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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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TENDERS.

IN THE MATTER OF THE TRADING WITH THE ENEMY AMENDMENT ACT, 1916.

The PUBLIC TRUSTEE invites

Tenders for the Purchase of

the Whole or any part of 119,660 Shares of £5 each, fully paid, in SIEMENS BROTHERS & COMPANY, LIMITED, vested in him as Custodian by an Order made by the Board of Trade, in pursuance of Section 4 of the Trading with the Enemy Amendment Act, 1916, and dated 9th August, 1916.

The issued capital of the Company consists of 120,000 Shares of £5 each, fully paid.

The purchasers, who must be British-born subjects, will be required to make a sworn Declaration as to nationality and freedom from foreign control on a form to be obtained from the Offices of the Public Trustee.

The purchasers will also be required to satisfy the Public Trustee as to their financial and technical ability to carry on the business of the Company as efficiently as heretofore, or otherwise to the satisfaction of the Government.

A report upon the Company's operations and affairs has been prepared by the Company, in conjunction with the Company's Auditors (Messrs. PRICE, WATERHOUSE & Co.), and with Messrs. TURQUAND, YOUNGS & Co. Copies of this report can be obtained, subject as hereinafter mentioned, together with copies of Company's accounts up to the 31st December, 1915, on written application to the Public Trustee, Kingsway, W.C.

All applicants will be required to satisfy the Public Trustee as to any matter which he may think fit to investigate before copies of such Report or accounts will be supplied.

Intending Tenderers who desire to inspect the property of the Company, should apply to the Public Trustee for an authority to do so.

Tenders must be delivered, sealed, to the Public Trustee, Kingsway, W.C., on or before Thursday, the 14th June, 1917 (NOT APRIL 2ND, AS PREVIOUSLY ADVERTISED), at Twelve o'clock Noon, and marked on the envelope, "Tender, Siemens Shares."

The Public Trustee does not bind himself to accept any Tender, and reserves to himself all rights in connection therewith.

Forms of Tender can be obtained from the PUBLIC TRUSTEE.

Dated this 8th day of February, 1917. 5043
C. J. STEWART, Public Trustee,
Custodian for England and Wales.

In the matter of the Supply of Raw and Partly Finished Material for Ministry of Munitions' Contract for Lorries, No. 94/MT/1153, BRITISH BERNA MOTOR LORRIES, LIMITED, invite

Tenders for the Supply of the

whole or any one item of the following:—

ITEM No. 1.

Channels and Angles for 200 Lorries, as per following list:—

Pieces per Chassis.	Length req'd in m/m.	Shape in Inches.	Lbs. per foot.
2.	5400	[5 in. by 2.044 in. ...	11.5
1.	900	Ditto	Do.
2.	3380	L4 in. by 2 in., if not available then— [4 in. by 1.727 in. ...	7.25 / 7.26
2.	900	[4 in. by 1.727 in. ...	7.25
—	650	L6 in. by 6 in. by ⅝ in.	90
4.	2280	2½ in. by 1⅛ in. ...	3.8
1.	1000	3½ in. by ⅝ in.	7

ITEM No. 2.

4 Tons Lead-coated Sheets, 2000 m/m by 1000 m/m by 0·9 to 1·1 m/m.

ITEM No. 3.

200 Crankshafts in Chrome Nickel Steel, as per drawing to be supplied.

ITEM No. 4.

Solid drawn Steel Tubes.

25 outside by 25 m/m inside diameter;		1400 ft.
40 " by 30 m/m " "		800 ft.
50 " by 38 m/m " "		1000 ft.
60 " by 50 m/m " "		100 ft.

1-ton Seamless Hexagon Tubes equally divided over sizes: 18/14, 21/16, 26/20, 31/26, 36/30, 41/35, 46/40, 51/45 m/m. outside and inside over flats.

ITEM No. 5.

	Outside.	Inside.
8-cwt. Copper Tubes	8 m/m by	6 m/m diameter.
2-cwt. "	35 m/m by	23 m/m "
1-cwt. "	35 m/m by	33 m/m "

ITEM No. 6.

20 tons of Steel for Bolts and Nuts in equal weights:—
(a) In round bars—80, 70, 60, 50, 40, 30 m/m.
(b) In hexagon bars—40, 35, 32, 30, 28, 25, 22, 20, 18 and 16 m/m over flats.

ITEM No. 7.

400 Front Springs, as per drawing No. 2490.
400 Rear Springs, as per drawing No. 2492.

ITEM No. 8.

200 sets of Small Stamp Forgings, 87 to a set.

ITEM No. 9.

10 tons Brass Strips—135 m/m by 0·14 m/m by not less than 40 to 50 metres long.

ITEM No. 10.

100 tons of Hematite, suitable for making Malleable Iron and Mild Steel Castings.

ITEM No. 11.

25 tons of Cylinder Iron.
25 tons of Flywheel Iron.

ITEM No. 12.

2 tons of Tin in Ingots.
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BRITISH BERNA MOTOR LORRIES, Ltd.,
Avonmore Road,
West Kensington, W.14.
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Production Manager Wanted,

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POSITION in connection with the Management of a large Manufacturing Company. Familiar with practical commercial problems and having experience of works methods. Capable of controlling estimating and selling staffs, and of undertaking substantial responsibility.—Replies should state experience and (approximately) views regarding salary, and should be addressed to "ALPHA," care of Sir WM. B. PEAT and Co., 11, Ironmonger Lane, E.C. 2. G 483

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Wanted, Rate Fixer for

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Also experience of repairs to plant, power house work not essential. Age not over 45. Good salary to right man.

Address, giving full particulars, G 485, Offices of ENGINEERING.

Wanted, Capable Works

ELECTRICIAN. Must be thoroughly experienced and first-class man, for large engineering firm in Midlands. No one already employed on Government work will be engaged.—Apply, stating age, experience, and salary required, your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and G 505.

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at termination of War, services of expert DESIGNER of heavy oil motors for small marine engine sets.—Particulars of experience and salary required, to be sent to G 490, Offices of ENGINEERING.

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DRAUGHTSMAN, thoroughly experienced in Dynamo and Motor design, over military age or ineligible. State experience and salary required, and when available. No person resident more than 10 miles away or already engaged on Government work will be engaged.—Apply, your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and G 510.

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Two Experienced Draughtsmen

(Mechanical) REQUIRED, for Monmouthshire, accustomed to lay-out of steel works and rolling mill plant. Applicants must apply with full particulars to their nearest EMPLOYMENT EXCHANGE, stating wages required, and experience, and quoting No. A 3112. No person already on Government work will be engaged. G 515

Wanted, Draughtsmen for

Jig, Tool, and General Design Work on Aeroplane Engines. Men used to motor car or high-class small engineering work preferred. No person already on Government work will be engaged.—Apply, your nearest EMPLOYMENT EXCHANGE, mentioning No. A 2982. G 375

Draughtsman Wanted in

Westminster office for Government work of high importance. Accustomed to design of light accurate electrical and mechanical instruments. Some workshop experience essential. Permanent position with good remuneration for capable man. —State full particulars of age, training, experience and salary required to your nearest EMPLOYMENT EXCHANGE and quote No. A 3071. (Applications from men at present engaged on War work cannot be considered.) G 437

Wanted, Draughtsman for

the mechanical design of large electrical direct current machines. Nobody engaged on Government work will be accepted.—Write or apply to the nearest Board of Trade EMPLOYMENT EXCHANGE, mentioning this Journal and No. A 2631. G 457

Wanted, Immediately,

Experienced DRAUGHTSMAN. One with knowledge of steel furnace construction and steel works machinery preferred. No one already employed on Government work will be engaged.—Apply, nearest EMPLOYMENT EXCHANGE, mentioning this Journal and G 501.

Wanted, Engineer's

DRAUGHTSMAN, with experience of ships' auxiliary engine gear. No one resident more than 10 miles away or employed on Government work will be engaged.—Address, stating age, experience, and salary required, G 491, Offices of ENGINEERING.

Required, in a Controlled

Establishment, London district, Competent Mechanical DRAUGHTSMAN, experienced in machine lay-outs and transmissions. No one already employed on Government work will be engaged.—Apply, your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and G 504.

Wanted for Iron and Steel

Works in Lincolnshire, SEVERAL First-class DRAUGHTSMEN, experienced in the lay-out and design of steel works' plant, rolling mills, hydraulic machinery, and general all-round work. No one already on Government work need apply.—Apply, stating age, experience, when at liberty, and salary required to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 3104. G 484

Draughtsman, Experienced,

REQUIRED for certified war work, of instrument type. Good all round knowledge essential.—Address, G 499, Offices of ENGINEERING.

Draughtsman Wanted, accustomed

to rolling mill work and general engineering. No person already on Government work will be engaged.—Apply your nearest EMPLOYMENT EXCHANGE, quoting No. A 3057. G 441

Draughtsmen.—Wanted

immediately, in London area, one for Gun work and one used to Machine Tool Design. Good salaries for competent men. No one already employed on Government work nor resident more than 10 miles away will be engaged.—Address, G 503, Offices of ENGINEERING.

Draughtsman Wanted with

good theoretical and practical training for steam auxiliary machinery, land and marine. No one engaged on Government work, or resident more than 10 miles away will be engaged. Preference given to man invalided from the Services.—Write, stating age, experience and salary, to DRAUGHTSMAN, care of STREET'S, 30, Cornhill, E.C. 3. G 518

Messrs. Rownson, Drew and

CLYDESDALE, LTD., 238, Upper Thames Street, London, E.C., have a VACANCY in their Engineering Dept. for a well-educated youth as APPRENTICE in the Drawing Office. Where good aptitude for drawing is shown, no premium will be charged and a sliding scale and pay given. G 507

A Large Firm of Engineers,

in the Midlands, have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4289, Offices of ENGINEERING.

LITERATURE.

The Flying Machine from an Engineering Standpoint. By F. W. LANCHESTER, M.Inst.C.E., Member Advisory Committee for Aeronautics. London: Constable and Co., Limited. [Price 4s. 6d. net.]

UNDER the above title Mr. Lanchester has reprinted the "James Forrest" lecture which he delivered to the Institution of Mechanical Engineers in the spring of 1914. To this some notes developing further particular points have been added as appendices, but the lecture itself remains in all essentials textually the same as when originally published. It is accordingly possible to compare Mr. Lanchester's views, as expressed over two years ago, with the conclusions established by practical experience of aeroplanes as weapons of war. Such a comparison gives a very favourable impression as to the depth of the author's insight.

In the earlier pages of the work under review Mr. Lanchester makes a highly interesting comparison between the tractive efforts needed to transport a given weight by land, water or air, and in this regard the atmosphere makes but a poor showing. The resistance offered by a railway train varies from ¼ per cent. of the total load up to 1 per cent. With pneumatic tyres on a good road the resistance which a vehicle has to overcome is 2 per cent. of the load, whilst with iron tyres on wood pavement it may amount to 2.2 per cent. and to 3.3 per cent. on macadam, increasing, of course, rapidly as the character of the surface deteriorates. At sea the tractive effort ranges from $\frac{1}{10}$ per cent. for an 8-knot cargo boat up to 0.70 per cent. for fast ocean-going liners. In the case of aeroplanes the tractive effort needed ranges, Mr. Lanchester says, from 12 to 13½ per cent. of the load, and it is 4 per cent. of the load even with rigid airships. Hence there seems no probability of heavy freight ever being transported through the air. Put briefly, to support a load on an aeroplane power must be provided which would be sufficient to raise it at the same speed up a frictionless inclined plane with a gradient of 7 to 8 per cent. Mr. Lanchester considers that a combined thermal and mechanical efficiency of 27 per cent. is attainable with aeroplane engines, and assuming that 10 per cent. of the total weight carried may be petrol, he takes the possible flight range as 600 miles, which might be increased to some 2,000 miles if the fuel supply at starting could be raised to one-third of the total weight. The principal difficulty in the attainment of exceptionally high speeds is, he stated in his lecture, the lack of suitable alighting grounds.

A noteworthy remark made in this opening section of the lecture (printed, it must be remembered, in 1914) is that "there is scarcely an operation of importance hitherto entrusted to cavalry that could not be executed as well or better by a squadron or fleet of aeronautical machines." Mr. Lanchester accordingly expresses the opinion that the number used by the services will in the future be counted, not by hundreds but by thousands, and possibly tens of thousands.

Mr. Lanchester next gives a short account of his theory of the motion of an aeroplane. This, which was the first to be published, agrees in its general characteristics exceedingly well with experience with actual machines. He shows that a flight path originally consisting of shallow waves above and below the mean horizontal may, under certain conditions, pass into other forms in which the steepness of the waves continuously increases, leading in the end to catastrophic instability.

Apart from the action of the pilot, this would inevitably occur with machines having a sensible moment of inertia, were it not counteracted by the fact that the thrust of the propeller, instead of being proportional to the resistance, as assumed in the theory, is approximately constant, and the effect of this is to damp out the tendency to an increase in the amplitude of the oscillations above and below the mean path. This argument was, we believe, the first indication that an automatically stable machine should be possible. A striking proof of the accuracy of this forecast has recently appeared in the daily press, which has reprinted a letter written by Captain Boelcke, in which he describes a fight with an English machine, which continued steadily on its way after the death of its pilot.

The fact that one flight path may be changed into another of a dangerous character, producing what Mr. Lanchester calls catastrophic instability, is discussed more fully in the next section of the lecture. If the attitude of a machine in flight alters, there is in general a "pitching moment" tending to restore the former condition. If a curve of this pitching moment be plotted against different tilts of the machine as abscissæ, this curve may either cut the zero line at one point or at three. In the former case the machine is safe against catastrophic instability, but if the curve has "three real roots," the machine is liable to turn upside down with disastrous results. The condition necessary to guard against this was given some years since in the author's "Aerial Flight," published in 1907–1908. He there showed that the load on the tail should be negative. This practice was, it appears, adopted with the B.E. 2 machine, where the tail in normal flight carried a negative load equal to 4 per cent. of the total weight.

Another highly interesting section is that in which Mr. Lanchester discusses the laws of resistance. Mr. Lanchester has always held that Langley was misled in formulating the idea that surface friction was negligible in the case of wing surfaces. He observes that by the deflection of the stream lines caused by the leading edge of an aerofoil the surface resistance is diminished and may even, in certain circumstances, appear to be negative; but in all cases the total resistance is higher than if due to surface friction only. This, in fact, constitutes the minimum resistance which a body passing through the air may have to overcome. By adopting suitable forms of wing, Mr. Lanchester holds that it may ultimately be possible to reduce the tractive effort needed to overcome the "flight resistance" to as little as 6 or 5 per cent. To this must, of course, be added the resistance due to the body of the machine. With low speeds of flight these are not serious, but they have become increasingly important as normal flight speeds have risen. Whilst with some machines the body resistance is equivalent to that which would be experienced by a plane of 3 to 4 sq. ft. in area driven broadside through the air, it should, by the adoption of suitable lines, be possible, Mr. Lanchester says, to reduce this to considerably less than 1 sq. ft. Taking the resistance due to the alighting chassis as reducible to 2 sq. ft., we get a total of 3 sq. ft., as against the 5 to 10 sq. ft. usual at the date of the delivery of the lecture.

In discussing the use of gearing between the engine and the propeller, Mr. Lanchester suggests that this would involve a loss of 4 per cent. Presumably this is based on motor-car experience, but such a loss is very much more than is found to be the case with turbine reduction gears, which appear to have an efficiency of about 98½ per cent. The pitch-line speed is, however, very high in such gears and the lubrication is probably correspondingly more effective.

A section which will be read with interest is that dealing with factors of safety, and it is quite likely that the author's views may not be accepted in their entirety by all. Many engineers appear to think that some *a priori* method of fixing such factors is practicable, but it is sufficient to take the case of a motor-car axle to show the essential fallacy of this assumption. No one knows what the actual maximum stress on such an axle may attain to when the car is driven at a high speed over a bad road. Even if this knowledge were available, there is little doubt but that the elastic limit would afford little or no indication as to the margin of safety available, since a material permanent set might not compromise the safety of the axle, though it might in some cases no doubt be highly undesirable on other accounts. In all such cases engineers can, in the end, do little more than apply the rule of three. If a certain dimension is found by experience to be satisfactory with a certain load, then in a similar but larger machine the results will probably be satisfactory if the scantlings are increased in proportion to the load. The difficulty, of course, comes in when it is necessary to pass from one type of machine to a different one, and this step is no doubt facilitated by having at hand a careful analysis of the nominal stresses in already existing machines. The Royal Aircraft Factory has, as a fact, found it desirable to reduce considerably the factors of safety at one time specified.

In dealing with questions of stability, Mr. Lanchester observes that few of the Continental writers on this subject have carried matters even as far as was done years ago by Professor Bryan and himself. He states that M. Bathezats' work, published in 1911, deals with not more than one-half of the subject, and does this so ineffectually that scarcely one of the conclusions arrived at can be taken seriously. The German works of Knoller and Reissner advance the subject nothing, and the second portion of M. Soreau's work was anticipated by the author's own studies published in 1897. His other conclusions are, Mr. Lanchester says, wholly erroneous.

Amongst the appendices to the main portion of his volume is the note on "The Stability of the Flying Machine as affected by Considerations relating to Propulsion," which was submitted by the author to the Advisory Committee. Mr. Lanchester had originally arrived at the conclusion that his results obtained on the hypothesis that during the oscillations of an aeroplane the propulsive force was always equal to the resistance would apply without material error to gliding flight. His experiments, made to test this, gave results of which those with the larger models were in fair agreement with the theory, but with very small models the discrepancy was somewhat large. In place of suppressing these abnormal results after the fashion practised by certain young demonstrators in technical college laboratories, Mr. Lanchester published them, definitely calling attention to the discrepancies. He now shows that when the Harper effect is taken into account, according to which the stability is greatly affected by the inclination of the flight path, these observations, made many years previously, fall duly into line.

The Construction of Roads and Pavements. By T. R. AGG, C.E., Professor of Highway Engineering, Iowa State College. New York: McGraw-Hill Book Company, Inc.; London: Hill Publishing Company, 1916. [Price 12*s.* 6*d.* net.]

A GLANCE through the catalogues of recently published technical works would show that the subject of road-making is attracting much attention in the United States, and that there is no lack of authorities prepared to offer guidance to Town and County Highway Boards, or to provide instruction for students in this branch of engineering science. This display of interest may be indicative of a desire to improve or extend the existing means of communication, whose capacity has grown inadequate to the demands of a rapidly increasing commerce and the needs of a more thickly inhabited country. In a sparsely populated district, where traffic is undeveloped, new settlers have to accept cheap and easily made roads, but with the increase of wealth and of transport the inconveniences of hasty and imperfect construction become intolerable, hindering social intercourse and preventing the use of heavier and more rapid vehicles. The author gives to social intercourse the first place in creating demands for improved highways, but the need of better business facilities is probably a more real inducement, and the main cause of dissatisfaction with the existing order. The advent of the motor, whether for business or pleasure, has emphasised the necessity for reconstruction with an urgency that cannot be overlooked. The reports of highway commissions, the machinery provided for testing roadway material, the summoning of conferences of experts, are all evidence of increased interest in road building, which the issue of an abundant literature does much to strengthen.

The need for this literary activity, however, is not apparent. The opportunities for the display of originality or ingenuity are not great, no new principles are involved, the choice of materials and the manner of their use are limited, improvements can only be looked for in details and accessories, the earth road and the macadamised road of the past remain what they were, the introduction of asphalt and bituminous carpets, with other modern innovations and luxuries, offer a slightly wider field, but the advantages and limitations of these are

well known to the experts. It is in attention to details that we must look for the best results, and by taking advantage of mechanical appliances for labour-saving we may expect the most economical. Tested experience will prove the best guide, and on this ground we welcome the author's plan of giving examples of good work in the various methods of construction, and of quoting from papers that engineers have submitted at recent conferences. The description of machinery that facilitates labour is also a useful feature.

In general, Mr. Agg follows the approved plan of describing the simpler and less costly methods of construction, as exemplified in the earth road, and of proceeding gradually to the more ambitious schemes, in which bituminous materials are extensively employed, with the view of reducing noise and dust or of diminishing traffic resistance. Sometimes the obvious seems to be insisted upon too strongly, but the amount of systematised information, sifted by experience and tested by frequent repetition, will be found both valuable and time-saving. From earth roads to sand-clay and gravel roads the transition is easy and natural. Of these latter, an expert stated at an American road conference that their economic value is so great, that they ought to constitute four-fifths of all the roads of a State. By gravel, he is careful to explain, "I do not necessarily mean the combination of sand and water-washed stone, but any combination of material which contains not less than 60 per cent. of metal in shape and size so that it need not be crushed, whether the binder be true sand, clay or marl." This definition might be made to include the macadamised roads so common in this country, and to which the term "waterbound" is applied, but, apart from the mechanical interlocking of the irregular-shaped granite, the binder is the cementing action of the granite dust, the result of traffic and abrasion, that fills the interstices between the stones. Of the two classes of roads there is little difference in the durability, traction resistance, cleanliness, cost of maintenance, &c., and we are inclined to regard this opinion as a testimonial to our somewhat despised, but very useful, waterbound macadam. The author states of these latter roads, and he will meet with a chorus of approval from the owners of motors, that "no matter how faithfully a macadamised road is maintained, it will be inadequate to meet the demands of excessive motor traffic unless treated with a bituminous binder to keep the surface intact."

Concrete roads and pavements are next discussed, and seeing that their construction is of comparatively modern development, the conclusions and recommendations adopted by the National Conference on Concrete Road Building, February, 1916, are entitled to consideration. It is noted, but without further comment, that the use of reinforcement in such pavements is increasing. Preference is given to the one-course pavement, but if the two-course be used, it is recommended that the top course should be placed within 20 minutes of placing the bottom. Of the value of expansion joints, whose utility has been much questioned of late, the conference does not express any decided opinion, but the American Concrete Institution favours such joints at intervals of 50 to 75 ft., the expansion material consisting of a layer of felt ½ in. thick. The addition to a concrete road of a bituminous surface of asphalt with stone chips is an obvious advantage. When well constructed it presents a uniform, easy-riding surface, with fair foothold for horses, and the motorist approves of it on account of its freedom from dust and for its smoothness.

Three chapters are devoted to pavements of vitrified brick, of wood, and stone block respectively, giving plenty of details and cautions for securing effective work. The choice of suitable brick, and the selection of proper materials generally, demand considerable experience. The author refers very fully to the various schemes that have been set up, in order to secure a uniform standard, by the fixing of definite tests. A full description of these is given, as, later, of the tests that apply to bituminous materials, and apparently he regards the procedure with approval as being trustworthy and protective of the purchaser's interests. But where the quantities are necessarily large and of variable quality, the method of samples can hardly be considered satisfactory. It may be that there is no alternative plan, but some of the examples referred to by the author are not calculated to give one much confidence. The clear description given of the various tests should leave no misunderstanding as to the character of the processes adopted, and individual judgment must decide on their value and effectiveness in particular cases.

Besides the chapters that describe the combination of asphalt and bitumins with concrete and other foundations, illustrative of modern practice and development, mention should be made of those which have reference to the selection of types and of the design of pavements or roadways. These chapters have an interest of their own, apart from the mechanical or engineering side. For in such matters the ratepayer and the student of social economy are interested as much as the road expert or the engineer. An insight into the field of social betterment is afforded: the development of aesthetics, as a factor in progress, is suggested; and the complications introduced by the conflicting interests of industry and of personal ease are clearly perceived. And above all tower the financial considerations, which so often form the determining factor in deciding between our necessities and our ambitions. Mr. Agg surveys the situation calmly, keeping in view the stern requirements of the present traffic census, but giving a little elasticity in favour of future extension. He is armed with statistics at all points, and is ready to give sound advice based on a wide experience.

Functions of a Complex Variable. By Thomas M. Macrobert, M.A., B.Sc. London: Macmillan and Co. [Price 12*s.* net.]

"Happy the engineer who is also a mathematician, but it is given to only a few men to have the two so very different powers." So wrote the great Evangelist of Practical Mathematics, himself one of the happiest of engineers. The present writer sat at his feet. Of course, the above quotation in its original setting had a useful bias, but it can be applied equally well in a wider sense. Recently, in this Journal, a leading article was devoted to "Relative Values," and it was pointed out how the draughtsman and toolmaker have many points of compensation against the "automatic" operative at present reaping his harvest. The same conclusions may be applied, as was pointed out, to the entire range of human activity, and with especial significance to the mathematical engineer. We have heard it said by a very eminent engineer that "Every hour given to the study of science is an hour lost to practice," and "Every scientific fact absorbed means a 'practical fact' displaced. For the human mind has only a definite and limited capacity." This is truly a terrible doctrine. A pint pot has a limited capacity, but all pots are not pint pots; Kelvin, Hopkinson and a score of others might be cited if it were necessary.

It is amazing how erroneous are the popular notions of mathematics and mathematicians. It is so rarely realised that mathematics is largely a matter of notation. Mathematicians as a class are not men of abnormal mental calibre. They have an aptitude and interest for a succinct notation which enables them to remember and reason upon properties of number and space which, expressed in everyday language, would be unwieldy. An engineer with the merest A B C of the notation can deal with kinematics, thermodynamics, strength of materials and a host of other things with ease and speed, while another with plain words is lost. This, of course, is no plea for the man who learns the notation without learning to know "things."

Thus we feel justified in reviewing such a book for engineers. The author has filled a want. His book is the most readable on the subject in English that we have seen; he gives graphical illustrations in plenty. The contents comprise practically all that a mathematical engineer or physicist should need. They include a very good discussion of the elliptic functions, the gamma functions and the equations of Legendre and Bessel. The inclusion of examples from mathematical physics would have altered the character and increased the bulk of the volume. A few references here and there, however, to the great treatises of Rayleigh, Love and Lamb would not only make the book more interesting reading for the engineer and physicist, but would widen the outlook of the mathematical student. A further suggestion for the author in dealing with future editions would be to include a brief chapter on the history of the subject. Few branches of mathematics are so interesting from this point of view; not many branches of knowledge show in the same space of time such astounding developments from such beginnings.

BOOKS RECEIVED.

United States Bureau of Mines. Bulletin 126. *Abstracts of Current Decisions on Mines and Mining. January to April*, 1916. By J. W. Thompson. Washington: Government Printing Office.

United States Bureau of Mines. Technical Papers. No. 86. *Ore Sampling Conditions in the West.* By T. R. Woodbridge. No. 130. *Underground Wastes in Oil and Gas Fields and Methods of Prevention.* By William F. McMurray and James O. Lewis. No. 136. *Safe Practice at Blast Furnaces, a Manual for Foremen and Men.* By Frederick H. Willcox. No. 157. *A Method for Measuring the Viscosity of Blast Furnace Slag at High Temperatures.* By Alexander L. Field. Washington: Government Printing Office.

Modern Gasworks Practice. By Alwyne Meade, Assoc. M.Inst.C.E. With an Introductory Note by Stanley H. Jones, M.Inst.C.E. London: John Allan and Co.

Institution of Gas Engineers Transactions, 1916. Edited by Walter T. Dunn. London: Offices of the Institution, 39, Victoria-street, Westminster, S.W.; E. and F. N. Spon, Limited.

Atoms. By Jean Perrin. Translated by D. Ll. Hammick. London: Constable and Co., Limited. [Price 6*s.* net.]

The Public Schools Year Book. The official book of reference of the Head Masters' Conference. Edited by H. F. W. Deane and A. Bulkeley Evans. London: Year Book Press, 31, Museum Street, W.C. [Price 6*s.* net.]

Manual of Reinforced Concrete. By Charles F. Marsh and William Dunn. Third edition, rewritten and considerably enlarged by the addition of much useful information and many new tables and diagrams. London: Constable and Co. [Price 10*s.* 6*d.* net.]

How to Drive a Light Car or a Cycle Car. By the Staff of *The Light Car and Cycle Car.* London: The Temple Press, Ltd., 7-15, Rosebery-avenue, E.C. 1. [Price 1*s.* 6*d.*]

Laxton's Builders' Price Book for 1917. London: Kelly's Directories, Limited, 182, High Holborn, W.C. 1, and Simpkin, Marshall, Hamilton, Kent and Co. [Price 4*s.*]

The Journal of the Institute of Metals. Vol. XVI. Edited by G. Shaw Scott, M.Sc., Secretary. London: The Institute of Metals, 36, Victoria-street, W.C. [Price 21*s.* net, 21*s.* 5*d.* post free.]

The British Journal Photographic Almanac and Photographer's Daily Companion, 1917, with which is incorporated the *Year Book of Photography and Amateur's Guide* and *The Photographic Annual* (*Figures, Facts and Formulæ of Photography*). Edited by George E. Brown, F.I.C. London: Henry Greenwood and Co., Limited, 22, Wellington-street, Strand, W.C. [Price 1*s.* net; 2*s.* cloth.]

The Western Front. Drawings by Muirhead Bone. Part IV. London: *Country Life*, Limited, 2A, Tavistock-street, W.C., and George Newnes, Limited. [Price 2*s.* net.]

L'Après-Guerre. Le Fer et le Charbon Lorrains. Par Maurice Alfassa. Paris: Belin Frères, 8, Rue Férode.

Industrial and Manufacturing Chemistry. By Geoffrey Martin, Ph.D., D.Sc., F.C.S. Volume I. London: Crosby Lockwood and Son. [Price 25*s.* net.]

How to Drive a Motor Car. Written by the Staff of "The Motor." Fourth edition. London: Temple Press, Limited. [Price 1*s.* 6*d.* net.]

A Handbook of Briquetting. By G. Franke. Translated by Fred. C. A. H. Lantsberry, M.Sc. In Two Volumes, each complete in itself. Vol. I—*The Briquetting of Coals, Brown Coals, and Other Fuels.* London: Charles Griffin and Co., Limited. [Price 30*s.* net.]

Honours for the Engineering Department of the Navy.—According to the *London Gazette* of Friday, March 23, the following honours have been conferred upon the members of the Naval Service named:—To be a Companion of the Distinguished Service Order. Engineer-Lieutenant Leonard Samuel Lovelace, D.S.O., R.N.R. The President of the French Republic has conferred the Order of Chevalier of the Legion of Honour upon Engineer-Commander (Acting Engineer-Captain) Charlie Broadbent, R.N., while His Majesty the King of the Belgians has conferred the honour of a Chevalier of the Order of Leopold upon Acting Flight-Commander Charles R. Edwards, R.N.A.S. The Distinguished Service Medal has been awarded to Engmn. George Henry Dodds, R.N.R.; Engine Room Artificer James Hutley Green, and Acting Engine Room Artificer Edward Lancaster. Mentioned in despatches are Chief Artificer Engineer Alfred Edward Thomas, R.N.; Engineer Artificer Albert William Morrison, R.N.R.; Stoker William O'Leary, R.N.R.; Stoker George Rees, R.N.R.; Stoker James Tomlinson, R.N.R.; and Engmn. Frederick Francis Feltham, R.N.R.

THE INSTITUTE OF METALS.

(*Concluded from page* 292.)

The meeting of the Institute of Metals was concluded on Thursday evening, March 22, in the rooms of the Chemical Society. On the members reassembling, the President, Sir G. T. Beilby, F.R.S., proposed that the remaining papers on the list, dealing with metal melting, should be taken in succession and discussed together.

Coke-Fired Furnaces.

The first contribution was one by Mr. H. W. Reason on "Coke-Fired Furnaces," which was not in print. The president thought the proceedings on metal melting would be incomplete without a reference to these furnaces, and he asked Mr. Reason to put forward his remarks. The author showed on the blackboard sketches of Hall's Patent Furnaces and of Wigley's Improved Furnace. In the original type of Hall's furnace the firebars could be removed from the inside only, and their removal being a somewhat difficult process, it was frequently necessary to get underneath the furnace to disengage them. This led to a first improvement, in which the firebars were made loose, when the air was able to rise up inside the furnace between the firebars and through the sides; the air could flow up at the sides even when the grate became blocked up at other parts. The furnaces were built round or square, but the square ones were preferred as being more efficient; they also burned less coke and were easier to keep in repair. A 100-lb. round crucible furnace had 3 in. of coke round the crucible; a square one had 1½ in. at the side. The furnaces had to be connected to stacks having a height of at least 25 ft. and not lower than the neighbouring stacks. The flues had to be vertical over a length of 12 ft. below nesting-in. The flues should be 9 in. by 9 in. for furnaces taking crucibles up to 160 lb., and 14 in. by 10 in. for 600-lb. crucibles. He advised the use of a third type of Hall's furnace, of which he also showed a sketch, this type having a cast-iron furnace bottom carrying the firebars, which were dropped on to it from the top; the ashes fell directly into the ashpit, and the firebars, being loose, could easily be removed. The speaker then exhibited models of the Wigley furnace bottom, showing the ease with which the firebars could be pulled out in front, thus rendering the clearing of the furnace much easier.

Electric Resistance Furnace for Melting in Crucibles.

The next paper taken dealt with an "Electric Resistance Furnace for Melting in Crucibles," by Dr. H. C. Greenwood and Dr. R. S. Hutton; it was read in abstract by the latter. We reproduced it in full on page 288 *ante*. In this the authors reviewed briefly their experience with coke and gas-fired furnaces, and described the electric resistance furnace which they had designed to melt nickel-silver alloys under more perfect conditions.

Ideals and Limitations in the Melting of Non-Ferrous Metals.

The secretary then read in abstract the paper having the above title, which was communicated by Mr. Carl Hering, Philadelphia, U.S.A. In this the author stated that perfection in the melting of non-ferrous metals pointed to reduction in the loss of heat, in the loss of metal, in the number of bad castings, in the consumption of crucibles, and in the cost of labour and plant per pound of good castings. In all high-temperature thermal operations insulation against loss of heat was, in practice, at best very poor. To obtain economy in heat the ideal was not only to insulate as well as practicable, but also to heat and cast the metal in as short a time as possible. From this standpoint the ideally perfect melting furnace, if such it could be called, was the electric fuse, in which the intended result was completed in a fraction of a second, hence the thermal efficiency was practically 100 per cent. With fuel heating, too great a rapidity of heating generally involved greater chimney losses; with electric heating there was no chimney loss. By heating with the electric arc there were higher radiation losses from the arc itself; in heating the metal by its own resistance the heat could be generated below the surface in the metal itself, thereby eliminating all heat transmission losses. Small high-speed furnaces were an approach to the ideal; on the other hand, the larger the amount of metal in a furnace, the less was the *rate* of heat loss per pound, *i.e.*, the loss per unit of time, because with a large body of metal there was less surface per pound exposed to heat losses than in smaller furnaces. Whilst the thickness of the heat insulation was of importance, the nature of the outside surface seemed to be a more important factor than was generally supposed, and the author gave various examples to illustrate this point. But over-insulation was also possible; the checking of the flow of heat would cause the furnace temperature to penetrate more deeply into the interior of the walls, and this might cause trouble. Superheating of the metal was one of the important causes of the consumption of much of the heat which could be saved; moreover, with zinc alloys there was in addition the loss by volatilisation of some of the zinc. In concluding his paper the author stated it was generally true that for the lower temperatures electric heat was more expensive per British thermal unit than fuel heat, but it was a mistake to consider this a criterion. What was wanted was the least cost per pound of perfect castings, and there were many other items which entered into the calculation besides the cost per British thermal unit If electric heating diminished the heat losses, the labour cost, the loss of zinc in brass and the crucible consumption, and increased the quality and uniformity of the metal, the perfection of the castings and the capacity of a plant, it might certainly be wise economy to pay more for the necessary electrical energy.

Metal Melting in a Simple Crude-Oil Furnace.

This paper, by Mr. H. S. Primrose, which we reproduced in full on page 287 *ante*, was then read in abstract by the secretary. As will be seen by reference to our columns, the author described the construction of the furnace, dealt with its operation, and pointed out the advantages of the oil-fired type.

New Crucible Gas-Fired Furnace.

The last contribution was one which was not in print, on a "New Crucible Gas-Fired Furnace," by Mr. T. Teisen, who illustrated his remarks with the aid of lantern slides. Mr. Teisen said the furnace he referred to was the invention of a Danish engineer, Mr. Axel Hermansen, of Ingelstad. Owing to the high prices of fuel and metal ruling in Scandinavia, it has been found necessary to build a new type of furnace to melt brass and copper alloys more economically. The first two furnaces built by the inventor, at the Svenska Metallverken, Vesteras, had been found a great success, and others were in course of construction. The furnace was designed in principle like a glass-melting furnace. Ordinary coal was used in the gas producer, and the furnace had a system for preheating the air and gas. The working was less expensive than that on the Siemens principle, for the latter was discontinuous in that there was a periodical reversing, whilst in the furnace referred to by the speaker the air and gas always flowed through the recuperator in the same direction. The gas was led from the producer to a central burner, and the furnace contained in a circular chamber six crucibles of the usual size. These were lifted out by tongs through the top, as in the current type of pit furnaces. The crucibles gave 35 per cent. more heats, there was a saving of metal, and the losses by oxidation were low. The metal was melted in a neutral atmosphere. Should a crucible break in the course of the melting, the metal would not be lost; it could all be recovered from a special pocket and charged afresh, perfectly clean, in another crucible. The temperature in the furnace could be very easily regulated by means of air slides. The furnace has been working at the Finspong works since 1915, where the consumption was about 3½ cwt. of coal per ton of 70:30 brass.

Dr. W. Rosenhain, F.R.S., who opened the discussion, said that owing to their varied nature the papers were not easy to discuss together. There was not much to say on the usual type of pit furnace apart from the heat losses, and this resolved itself into a question of conductivity *versus* radiation. When a furnace was built into the earth, it was built into a good conductor of heat, and it would therefore pay to surround it with a heat-insulating layer to prevent loss of heat in the earth. In regard to the furnace referred to by Mr. Teisen, he (Dr. Rosenhain) was surprised this should come forward as a novelty, for it was a commonplace furnace in many directions, and if non-ferrous metal-melters had not adopted it extensively it was probably owing to the "watertight compartments" which existed and prevented the interchange of knowledge between steel makers, glass manufacturers and brass makers. The furnace illustrated by Mr. Teisen was of a neat and efficient type. There was a great deal to say in favour of the continuous flow of the secondary air in ducts heated in the reverse direction. It was an extremely efficient method; the construction was no doubt rendered a little more complicated by the provision of airtight ducts. He (the speaker) had built a small furnace of practically the same type, using coal gas as fuel and pre-heated air, from which he had obtained good results. As for electric furnaces, they were going to be a clearly important feature in the metal industries and their future was assured. They kept the metals pure; the specifications referred to pureness of metals, and everybody knew that they should be produced pure. It was necessary in the process of melting to have an absolutely accurate control of the gases surrounding the metal, and in that respect the electric furnace was far beyond the gas furnace. Besides, in an electric furnace the heat could be generated at the point where it was wanted. The atmosphere in a gas furnace was not homogeneous, oxidation occurred in some parts and reduction in others, whilst in an electric furnace the atmosphere could be controlled. With steel, the high-temperature arc furnace had advantages over the resistance furnace. But electricity had to compete in the matter of current cost. In regard to the atmosphere in an electric furnace, one could be introduced to get over that difficulty. At the National Physical Laboratory, added Dr. Rosenhain, he was working with a resistance furnace, and the Laboratory had profited by the work carried out by Dr. Greenwood and Dr. Hutton; whether the furnace would be economical remained to be seen. At all events, the electric furnace in future would be an important factor, especially in the costly alloys industries, and both for melting and for the heat treatment of alloys, owing to the fact that the temperature was under accurate control and also uniform throughout.

Sir Gerald Muntz, who followed, said he was afraid some members on reading the different papers would be reminded that it was better to bear the ills we had than to fly to others we knew not of. Some of the metallic losses touched upon would seem to lead to remarkable figures which, to him as a manufacturer, suggested 10, 12 and even 25 per cent. loss of metal in casting; his experience in the matter of castings pointed to an average loss of 1½ per cent., and he had known it to be as low as ⅝ per cent. in coke-fired furnaces. This matter should therefore be looked into. The absorption of gases by the molten metal was in brass castings one of the greatest difficulties, and unless the metal were protected there would be absorption of gases and a spongy metal would be obtained. Some of the authors had referred to fluxes; he asked what these fluxes really were, whether natural fluxes or not, how and when they were applied, and if they were skimmed off or left in. In regard to the nature of the gases absorbed by brass, bronze, cupro-nickel and copper, it was not known at what temperature they were absorbed, neither what were the gases absorbed, nor how absorbed. The question of temperature when dealing with high-class bronze was the crux of the whole question; the small porosities which occurred were principally the effect of the pouring temperature. He had tried both the Wigley and the Hall furnaces; they reduced the coke consumption and also the proportions of ash, and this latter point was an advantage not to be disregarded in towns, where the disposal of the ash was a difficult problem. It was the general rule to put such furnaces in groups, when there was not a so very great loss in temperature. He agreed with Dr. Rosenhain that the electric furnace was the furnace of the future owing to the facility with

which the temperature could be controlled and maintained uniform; this was a vital point, and another was that with the electric furnace there was no danger of gas absorption. There was also freedom from the danger of dirt getting into the metal; the dirt danger was due to carelessness on the part of the casters.

Mr. C. W. Speirs said that the trouble he had experienced when he first commenced experimenting with electric furnaces was the difficulty of making contact; it was not till 1913 that he really took up the question of electric crucibles. He showed on the blackboard a part section of the crucible he made having a metal contact-piece. The crucible had a very long life; the power taken was 13 Board of Trade units for a capacity of 150 lb. of brass. The current pressure was about 50 volts.

Mr. W. R. Barclay, who followed, expressed the opinion that there were two difficulties which confronted the members in the discussion; one was in regard to confining oneself actually to the melting of metals, and the other was that of transferring the atmosphere which reigned in the room to the shop. There were both advantages and disadvantages attendant upon the use of gas, oil or coke furnaces—leaving out for the moment the question of electric furnaces—and the manufacturer was in a difficulty when he contemplated the use of either coke, oil or gas. A great deal depended upon the human factor, and it was difficult to arrive at comparisons. As an instance, Mr. Barclay stated that he had two shops, and he was unable to arrive at a comparison between them because of the different set of men employed in each case. Experimental laboratory work was different from the taking charge of an actual furnace in all the various operations; the technical adviser had to work hand-in-hand with the men. If a method secured a saving in coke but led to a reduction of say 25 per cent. in the metal melted, he failed to see where the advantage came in. A metallurgical expert had to go in wholehearted co-operation with the workman and, if possible, lift him to a higher level, or he could endeavour to eliminate the human factor as far as possible by the introduction of mechanical devices. The caster as a workman was chosen for his muscle rather than for his brain, and if one could eliminate the muscle and institute the brain, other results would be obtained. In order to illustrate some of the difficulties encountered, Mr. Barclay added that for the last twelve months he had had to work with market gardeners and schoolmasters, and had been trying all that time to turn them into practical metal melters. He would therefore suggest to furnace designers that there were two lines on which to work, one was to raise the workmen and the other to go in for overcoming the mechanical operations, *i.e.*, to eliminate the muscle. In regard to the electric furnace, he believed in its future, and was glad that there had been one paper on this type of furnace.

Mr. D. C. Highton said he found the papers and the discussion upon them to be most interesting. He had pinned his faith hitherto to the coke furnace; he had investigated with others, but had returned to the coke-fired one. He would, however, welcome a cheap and satisfactory gas furnace, and also an electric furnace. When these other types of furnaces were put before intending users his experience was that the real charges were difficult to arrive at for comparison, several items of cost being left out or taken into account separately. But the heat losses in coke-fired furnaces were so great that he felt the days of these furnaces were numbered. He would suggest that all the items of cost in the different papers be reduced to one standard, so as to facilitate a comparison between the different methods described. He was greatly interested in hearing Dr. Rosenhain's remarks on the heat insulation of the pit furnaces from the surrounding earth; these furnaces were now built closer together than was formerly the case, with the result that an increase in thermal efficiency was obtained. His (Mr. Highton's) costs on heavy total melts, including wages, bonus on output, war bonus and repairs to the furnace, worked out at 42*s.* 7*d.* per ton for metal one-third brass and two-thirds phosphor bronze, gun-metal and copper. His various figures were much ower than those given in Mr. Hocking's paper. Thus Mr. Hocking's crucibles cost under coke 39.8 shillings per ton and under gas 26.8 shillings per ton; his own figure was 8.8 shillings per ton. He also found that Mr. Hocking for a ton of coke melted 1.8 ton of metal; whilst his (the speaker's) firm melted 2.34 tons of metal. Moreover, his (the speaker's) crucibles lasted nearly 24 heats per crucible in the 100-lb. size. He confirmed the remarks made by the last speaker in regard to actual foundry work.

Mr. L. C. Harvey asked whether Dr. Hutton's electric furnace was of a new design and whether it had any decided advantage over other known electric furnaces built for similar purposes. He sketched on the blackboard a furnace which he built, having tube resisters and alternating layers of insulating material, and showed the location of the heat zone; the furnace was covered, and he could always pass gas or another substance through it to produce a reducing atmosphere. In a tilting furnace the heat from the lining was taken into the melting chamber again and was not wasted; these furnaces were above ground, and it was better to make them with a double lining. Skilled men were required to operate pit furnaces, but he (the speaker) could put any man on his electric furnace, provided supervision were exercised by a good foreman. The human factor was eliminated, except as regarded the pouring temperatures, and these could be seen to by the head caster.

Mr. T. Teisen, who followed, said that in Sweden they had tried all types of furnaces. The electric furnace was suitable for steel, but in melting brass it had been found that the loss of zinc was great. It was suitable for copper and nickel. With an electric furnace the temperature could be easily controlled, but a large amount of current was liable to be lost in the regulation, and this spoke against the electric type.

Professor Turner, who next spoke, said that owing to the wide range covered by the papers it was difficult to discuss all the different points raised. With reference to the figures obtained in Birmingham works, and given by Mr. Walter in his paper on metal melting by high-pressure gas read in the afternoon, these figures had been adversely criticised. He would remind the members that the tests recorded had applied to over 1,000 tons of metal, and had covered a period of 12 months; there had been no experts present and the figures had been given by the works themselves. Coke and gas fuel each had their importance, and with regard to the shape of the furnaces experience had shown that with those fired with coke the square section was of advantage, since less coke was required and repairs were easier. In the matter of loss of heat by conduction, this was important in some instances; in the case of blast-furnaces, Sir William Bell had pointed out that radiation losses were extremely low. In the buried furnaces, when these were placed side by side the heat losses were very small. Professor Turner added that the success of a furnace depended upon what was thrown away; in the case of heat, this might be thrown away up the chimney, and unless the volume, heat and composition of the gases flowing up through the chimney were all known, there could be no scientific control, and an investigation in that direction should be made. In regard to the metal losses, the differences which had been quoted were not so great as would appear at first sight; the weight of the gates, runners, &c., came in in some instances, and Mr. Walter had given the weights of the finished castings. Professor Turner then showed a sketch of a simple electrical means of melting a small quantity of metal, by using two small horizontal carbon electrodes, 3 in. in diameter, and placing between the two tips a dish made of clay and graphite; heat was developed very quickly, and by this means one could easily melt a few pounds of white pig iron.

Mr. A. B. Roxburgh referred to the present labour difficulty; the men hardly ever worked full time. For a period of six months his total gas consumption had been 766 cub. ft. per cwt. of metal melted, this being 70 : 30 brass for the manufacture of extruded bars. In the melting of copper his average was rather less than 5 cub. ft. of gas per lb. of metal poured. In a swarf furnace it was 12 to 14 cub. ft. per lb. of metal melted out. He had found that the combustion space in some furnaces was somewhat too large, and by reducing this he had obtained a combustion of rather less than 5 cub. ft. of gas per lb. of metal. Gas melting had been adopted by some works owing to the difficulty of obtaining coke.

Mr. H. H. A. Green expressed the opinion that the Institute should form a sub-committee for looking into the whole question of melting and tabulating all the points surrounding the subject. By this means of standardisation the members could then easily arrive at a comparison between the various methods.

The chairman asked for a cordial vote of thanks to the members who had sent in contributions; this was heartily responded to. The usual votes of thanks to the Chemical Society for the loan of their rooms and to the president terminated the proceedings.

REFRACTORY MATERIALS SECTION OF THE CERAMIC SOCIETY.

THE first ordinary meeting of the recently formed Refractory Materials Section of the Ceramic Society was held at the University, Leeds, on March 13, the chair being taken by Mr. William Oates. There was a large attendance at the morning, afternoon and evening sessions.

The morning session was occupied by two papers, the first by Professor P. F. Kendall, M.Sc., F.G.S., and Mr. A. Gilligan, B.Sc., on "The Clays of Northern and Central Yorkshire," and the second by Mr. J. A. Audley, B.Sc., on "The Use of Zirconia as a Refractory Material."

It was stated that zirconia is widely distributed, but generally in small quantities, and chiefly in the form of zircon, which is zirconium silicate, $ZrSiO_4$. In 1892 a much more abundant source was found in Southern Brazil, where extensive deposits of the mineral baddeleyite occur, containing 80 to 94 per cent. (and sometimes up to 98 per cent.) of zirconia, with some silica and ferric oxide, &c. The average percentage of zirconia in baddeleyite is about 84. Baddeleyite also occurs in Ceylon, North America, Australia and the Ural Mountains in Russia. Zirconia is produced as a by-product from the monazite sands, whence are extracted the thoria and cerium dioxide used for the mantles of incandescent gas lights. Indian monazite sands are specially rich in zircons. Zircons also occur in Natal, &c. Baddeleyite has a hardness of 6.5, specific gravity 4.4 to 6, the colour ranging from white and light grey to very dark grey, and sometimes brown and dark green. It is insoluble in acids, except hydrofluoric acid, but is easily attacked by fusion with potassium hydrogen sulphate.

Zirconia has a high melting-point (nearly 2,000 deg. C. for the ordinary raw zirconia, and very much higher when purified to 98 per cent. ZrO_2), but can be melted and volatilised in an electric furnace. It offers strong resistance to both acid and basic slags, and to fused cyanides and alkalies, being seriously attacked only by melting bisulphates and fluorides. Its conductivity for heat is remarkably low, the linear coefficient being 0.00000084, close to that of quartz glass; hence it can be plunged while red-hot into water without cracking or breaking. All these properties are possessed by native zirconia containing 80–84 per cent. (or more) ZrO_2. Its low conductivity for electricity (except when strongly heated) makes it well adapted for insulating purposes, as in electrical heating apparatus.

At the Faraday Society's recent discussion on refactory materials Dr. W. Rosenhain stated that with crude zirconia containing 74.72 ZrO_2, 13.16 SiO_2, 3.5 Fe_2O_3, 1.6 MnO, 1.10 Al_2O_3, and 2.16 CaO—the rest being loss on ignition—bricks could be made, bonded, if necessary, by a little china clay or fireclay, which would resist respectably a temperature of 1,650 deg. C., but that for the best results the material should be burned to a much higher temperature than that to which it was to be exposed, in order to avoid cracking. He added that this crude zirconia, which seems to be a rather low-grade material, could be greatly improved by treatment with dilute acid (sulphuric or hydrochloric) to remove part (about half) of the iron oxide. He also pointed out that though zirconia is very apt to carburise at high temperatures, it will not do so in an ordinary furnace, because the atmosphere there is oxidizing.

Latterly, zirconia has been used in the Blériot headlights for automobiles; a rod of zirconia is heated in a blowpipe flame fed with oil vapour and oxygen. Zirconia is also used in the filaments of the Nernst, Sanders and Zernig electric lamps. Native zirconia makes a good lining for electric furnaces of the arc type.

The supply of zirconia in commercial quantities at

comparatively moderate prices enables it to be used for making refractory bricks, the special properties of the material compensating for high initial cost as compared with, say, magnesite bricks in a furnace lining. It is recorded that a zirconia-lined hearth of a Siemens-Martin furnace in a steel works at Remscheid, after four months' continuous working at high temperature, was still in good condition and likely to last at least four months longer before renewal would become necessary. It was calculated that in actual maintenance costs there was a saving of over 50 per cent. in favour of zirconia lining as compared with the refractory lining usually employed. A mixture of about equal parts of zirconia and carborundum (the latter coarser-grained) is said to be highly refractory, without showing the usual tendency of zirconia to crack and lose coherence.

A refractory mixture for zinc muffles, consisting of 1 to 10 per cent. zirconia, 33.3 per cent. clay, and burnt fireclay, is specified in German patent 287122 (1913). In German patent 284385 (1914) Knöfler recommends zirconia, with or without titanium dioxide, for making porous refractory masses for flameless surface combustion.

Respecting the commercial value of zirconia in Germany before the war, it may be noted that crude material, with 85 per cent ZrO_2, was sold in lumps for 31*l.* per metric ton (of 1,000 kilograms, or 2,204 lb.), while powdered preparations containing 90 to 98 per cent. of ZrO_2 cost from 35*l.* to 50*l.* per metric ton. These figures, as well as some other information, were given by Messrs. Ridge-Beedle and Co., of Glasgow, who also sent a sample zirconia brick and a specimen of the raw zirconia used in making it.

E. Podszus recently stated that zirconia which had been heated to over 2,000 deg. C., and especially fused zirconia, is well suited for making refractory ware, having lost the tendency to crack and fall to pieces shown by raw zirconia used without a bond. The fused zirconia is finely ground, part of it so very finely that it assumes a colloid form and gives sufficient plasticity to the whole, after which it is cast in plaster moulds. The burning temperature is 2,300–2,400 deg. C., the furnace used being chiefly made of fused zirconia and cylindrical in shape. The fuel is coal-gas, petroleum or acetylene, with air-blast until the highest attainable temperature is reached, when a blast of oxygen is substituted for the air. With finely ground zirconia the total contraction is about 20 per cent. Further details will be found in *Zeitschrift für angewandte Chemie*, 1917, 30, 17–19; abstracts appear in current issues of the *Journal of the Society of Chemical Industry*, and the *Brick and Pottery Trades Journal*.

O. Ruff and G. Lauschke recently investigated the refractoriness and other properties of zirconia, alone and mixed with certain other oxides. They sought to discover the most suitable oxides and the most favourable mixing proportions for using with zirconia, and the most favourable firing temperatures, as well as refractoriness and reducibility of the oxides, in order to produce sufficiently compact objects to withstand a temperature of more than 2,000 deg. C.

The materials used, besides raw zirconia (with 83.53 per cent. ZrO_2) and pure zirconia (with 98.73 per cent. ZrO_2), were silica, beryllium oxide (or glucina) magnesia, alumina, thoria, and yttria. To some of the zirconia masses was added 1 per cent. starch, as either dry starch or starch paste. The mean melting temperature ascertained for six trials of zirconia was 2,563 deg. ± 10 deg. C. Ruff and Seiferheld earlier found 2,615 deg. Magnesia began to volatilize at about 2,000 deg., but was not melted at 2,694. Kanolt had found a melting temperature of 2,800 deg. ± 13 deg. Alumina melted at 2,005 deg. and 2,008 deg.; Ruff had earlier found 2,038 deg. ± 10 deg.; Kanolt had found 2,031 deg., and more recently 2,050 deg. ± 5 deg.

Beryllium oxide and yttria each melted above 2,400 deg., but thoria was not melted at 2,790 deg., though it began to volatilize at 2,450 deg.

Beryllium oxide, or alumina, lowered the melting-point of zirconia somewhat, but in no case below 2,400 deg. Thoria or yttria scarcely lowered the melting-point of zirconia, though either alone is easily reduced to carbide. Magnesia, and still more silica, is too apt to volatilize, even when mixed with zirconia.

As regards falling to pieces, crucibles of pure zirconia did not fall to pieces at all when burned at 2,000 deg., only slowly when burned at 2,200 deg., and quickly when burned at 2,400 deg. The addition of 3 per cent. alumina greatly reduced the tendency to falling to pieces; and 6 per cent. completely prevented it even when burned at 2,400 deg.

The general conclusion was that for burning at 2,000 deg. the most suitable addition is about 1 per cent. alumina, at 2,200 deg. about 1 per cent. thoria, and at 2,400 deg. about 1 to 3 per cent. yttria. Large additions are useless, and increase the porosity.

Mr. B. J. Allen read a paper on "A Process of Manufacturing Heavy Fireclay and Similar Articles." This had reference to a casting process which involved exhaustion to give reduced pressure. In a modified process electric currents were utilised. The process was stated to be applicable for making such objects as glass pots, &c.

Dr. J. W. Mellor communicated by title two papers, one by Professor H. B. Cronshaw, of Galway, on "A Curious Mineral occurring in a Magnesia Brick," and the other by himself, entitled "Can the Firing Temperature of Clay and Silica Goods be estimated from the Microscopic Appearance of the Finished Product?" His conclusion was in the negative. Dr. Mellor then proceeded to read a paper on "The Spalling of Magnesite Bricks." The amorphous powder obtained by calcining magnesite has a specific gravity as low as 3.2, while the crystalline forms of magnesia may have a specific gravity as high as 3.7. Some powdered magnesite bricks were found to have a specific gravity of 3.44, and for these to obtain the maximum of 3.7 would involve a contraction of 7 per cent. The specific gravity 3.44 works out to the equivalent of 40.5 per cent. of the high specific gravity form, and 59.5 per cent. remains to be converted.

On account of low conductivity for heat, the contraction of the magnesite lining of a high temperature furnace occurs mainly on the hot face, and with the possibility of 7 per cent. contraction it seems natural enough that the lining should be very liable to crack and spall. The bricks break down, not by ordinary wear and tear, but rather by the repeated spalling or flaking of pieces up to 2 in. thick.

Magnesite which has been strongly calcined, so as to give a material of the maximum specific gravity, will not spall because of internal strains such as are set up when two parts of the same brick are contracting differently.

Magnesia, from calcined magnesite, evidently occurs in two forms, one with the lower specific gravity 3.2, which readily absorbs gases, moisture, &c., and readily dissolves in mineral acids, and one with the higher specific gravity 3.7, which resists the influences mentioned. By calcining a sample of raw magnesia repeatedly between 1,300 deg. and 1,250 deg. C., and similar samples at other temperatures, keeping the conditions as nearly uniform as possible, the general results showed that (1) the conversion of low specific gravity magnesia to high specific gravity magnesia is relatively slow, (2) the higher the temperature of calcination the faster the transformation, and (3) the different types of magnesite have their own specific rates of conversion. The rate of conversion is apparently faster with the more ferruginous magnesites—Austrian being quicker than the purer Grecian. The material must thus be *retained* at a high temperature for a definite time to ensure satisfactory results.

Another important cause of spalling is the shrinkage caused by the closing of the pores. A magnesite brick which had been in the electric furnace had porosity 11.0 per cent. near the end exposed to the heat from the electric arc, and 19.4 per cent. at the cooler end. The corresponding difference in contraction must be added to that due to change in character of the magnesite. From the porosities and specific gravities it is found by calculation that the face of the brick must have contracted 15.8 per cent. by volume, or 5.8 per cent. linear, when exposed in the lining of the electric furnace. The separate effects are 5.99 per cent. contraction by shrinkage of magnesia, and 9.81 per cent. contraction by closing of pores. The three most important factors controlling the porosity of the finished brick under the present conditions of manufacture are—(1) the finishing temperature of the kiln, (2) the pressure used in making the bricks, and (3) the grain-size of the materials.

The strains set up by a sudden chilling of the hot furnace may aggravate spalling primarily produced when bricks are made with too high a porosity from imperfectly shrunk magnesia.

If no serious factor has been overlooked it ought to be possible to determine by preliminary tests whether a magnesite brick is likely to spall seriously, and the manufacturers ought to be able to obtain definite objectives in order to reduce spalling to a minimum. For the purpose of a specification for magnesite bricks a contraction test analogous with that of the Gas Engineers' specification could be devised, or permissible limits for the proportion of unconverted magnesia, and also for porosity, could be arranged.

Mr. C. Dressler next read a paper on "The Dressler Kiln," with special reference to a form adapted for annealing steel, which, it was claimed, gave complete and easy control. The construction cannot easily be made intelligible without illustrations, which on this occasion took the form of lantern slides.

Professor J. W. Cobb, B.Sc., in the evening lectured on "Temperature Measurements in Clay Works Practice." All the usual appliances employed for the various heating operations were reviewed. Stress was laid on the necessity for plainly marked milk-glass scales in the case of the mercury thermometers. For temperatures of 250 deg. to 450 deg. C. a mercury thermometer with compressed nitrogen above the mercury was mentioned as suitable, and for temperatures ranging from 450 deg. to 1,400 deg. or higher a thermo-couple consisting of wires of platinum and platinum with 10 per cent. of rhodium respectively. The construction and calibration of these thermo-couples were carefully explained. Reference was also made to the copper-constantan, and the nickel-nichrome couples. These cheap couples cannot be used above 600 deg., and are apt to deteriorate. For many purposes recording instruments are useful, and the Thread Recorder of the Cambridge Scientific Instrument Company was described and shown in action by way of example.

About 1,400 deg. or 1,450 deg. it is preferable to employ an instrument depending on the fact that the total heat radiated is proportional to the fourth power of the absolute temperature, and the best known of these, the Féry Radiation Pyrometer, was described, with the necessary precautions.

Reference was also made to a form of optical pyrometer in which the brightness of a lamp filament alters with varying resistance. It is focused so that the image of the filament can be formed on the background so that the image is of the same brightness as the background itself, and so becomes invisible.

Experience has shown that the same effects can be produced by a lower temperature maintained for a longer period as by a higher temperature acting for a shorter period. When working with silicate mixtures, Professor Cobb obtained the same effect in three days at 1,200 deg. as in six hours at 1,300 deg.

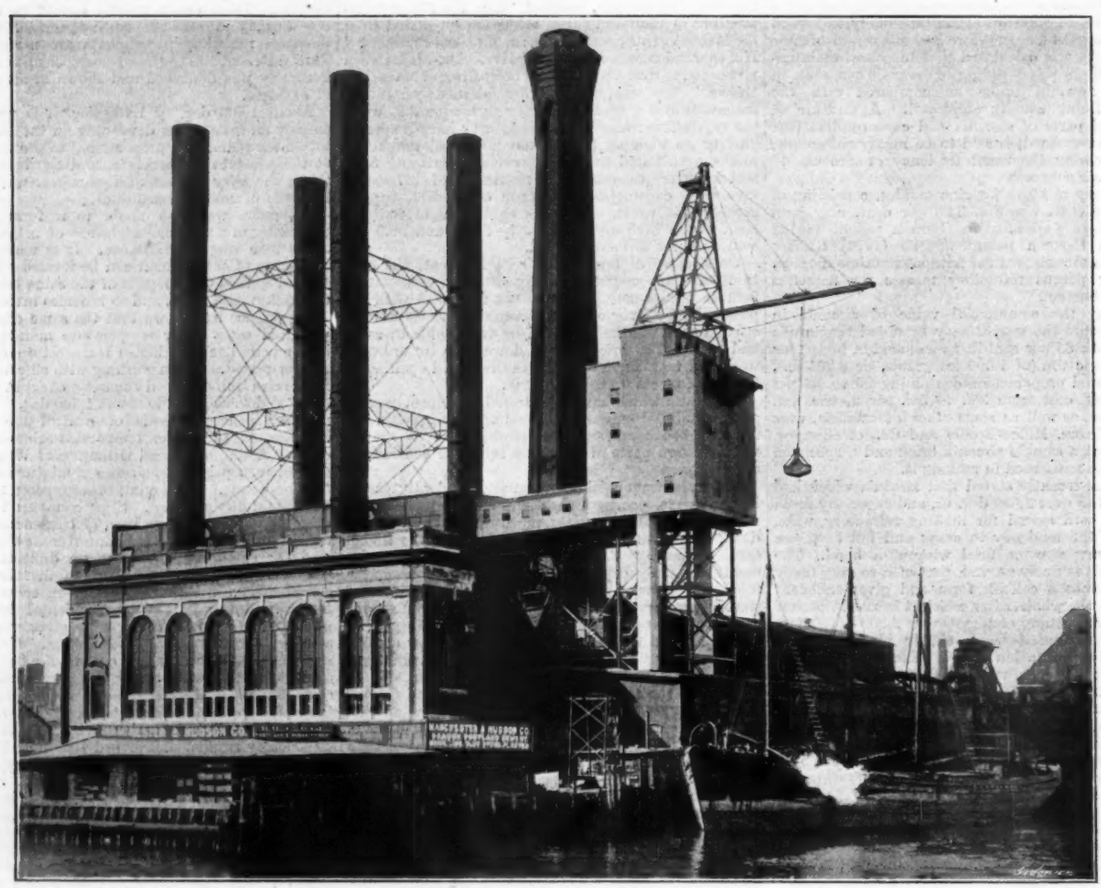
Hence other methods of control are necessary in order to show the temperature-time-atmosphere effect. A simple method is the use of Watkin's Heat Recorders, consisting of a series of mixtures of different melting-points. Each mixture is supposed to represent a standard fluxing effect. Seger cones are the classical example, and they have been of tremendous value to the ceramic industry. It is unfortunate that they are made so small, because they are difficult to see in position. Professor Cobb had to increase the size considerably. Small cones in a furnace are very apt to be unduly affected by accidental heat waves, whereas the use of a larger cone gives what may be called a thermal inertia to the system. He had found it advantageous to set two cones with flat bases and one side vertical, so that the two vertical faces should come together. Pressing the cones is simpler when the cones are made wedge-shaped, and by making the top of the wedge half the size of the bottom they gave satisfactory results. He hoped that now Seger cones were being manufactured in this country their disadvantages would not be perpetuated. For some purposes preference is given to Holdcroft bars instead of Seger cones; they are also standard silicate compositions, their use depending on collapse of a small beam. Buller's rings are also standard compositions, depending on contraction measured by a simple multiplying device. Wedgwood's pyrometer was also alluded to. Various appliances were exhibited, many of them in action.

Shipbuilding in Canada.—Efforts are being made to increase shipbuilding in Canadian yards, the tonnage of ships built in Canada during the last fiscal year having been only 13,497. The Minister of Marine in a recent speech at Montreal stated that in order to stimulate immediate construction and to pave the way for permanent and increasing shipbuilding after the war, the Government had granted permission for the export of ships to be constructed on both the Atlantic and Pacific seaboards. One of the conditions on which permits for the building of these vessels had been given was that they should not engage in any enemy trade, and another was that no demand should be made on Great Britain for materials, machinery or labour to build them.

Technical Library to Aid German Industry.—According to a recent article in the *Frankfurter Zeitung* and an interview with a prominent librarian at Frankfort, plans are being considered for the establishment of a general technical library at Frankfort-on-Main, to be open for public use. One of the leading city libraries has become interested in the project, and a beginning already has been made. It is said that the plan is unique among the cities of the German Empire. In this manner a broader spirit of scientific and technical investigation will be fostered. An attempt will be made to furnish technical information which will have an historical as well as a purely scientific value. Technical libraries have existed previously, but they have not been open to the general public. The plan that is now under way would combine the private and semi-private libraries and put them under the control of one of the established city libraries at Frankfort. The library chosen for the purpose is the Freiherrliche Carl von Rothschildsche Öffentliche Bibliothek. In addition to technical books it is stated that the chief technical magazines of Germany and of the technical world are to be placed at the disposal of the public. A special feature will be the department for patent publications. Not only will the important German patent publications be provided for the library, but an attempt will be made also to furnish as broad an international list as possible.

COAL-HANDLING PLANT AT NARRAGANSETT, PROVIDENCE, R.I., U.S.A.

CONSTRUCTED BY THE C. W. HUNT COMPANY, ENGINEERS, WEST NEW BRIGHTON, N.Y., U.S.A.



THE coal-handling plant at the new power house of the Narragansett Electric Lighting Company, Providence, Rhode Island, was supplied by the C. W. Hunt Company, of West New Brighton, N.Y., U.S.A., and is designed to meet conditions common to a power house located on tide water. The greater part of the coal is shipped by water and unloaded at the plant. A small portion of the coal is received from other sources, and provision is made to handle this coal by machinery.

The coal-handling plant, which we illustrate on the present page and page 326, consists of a Hunt one-man steam tower, operating a 60-cub. ft. grab bucket. The entire tower structure is steel; the engine rooms are enclosed with cement plaster, the appearance being in harmony with the power house.

The hoisting equipment is one Hunt direct-connected two-drum engine, with cylinders 15 in. in diameter by 15-in. stroke, and one Hunt direct-connected single trolley engine, with cylinders 10 in. in diameter by 12-in. stroke. The height of the boom from mean low water is 140 ft. A Hunt pivoted bucket conveyor is installed in the tower structure, and elevates coal from a pit beneath the tower to a hopper above the coal cracker. The steam supply is obtained from the boiler house. The maximum hoisting capacity is 250 tons per hour. From the tower receiving hopper the coal passes over a screen, and the lumps are broken in a 36-in. coal cracker, driven by an electric motor. The sized coal is delivered to a hopper having a gate on each side. This hopper discharges the coal to two 2-ton Hunt automatic railway cars, where it is weighed, and the cars, after being started automatically, deliver it to a 1,200-ton overhead storage bunker in the boiler room. From this bunker delivery is made to stoker hoppers through 16-in. Hunt duplex gates and fixed down pipes, each hopper being served by a single pipe, so designed that a hood covers the entire length of the stoker hopper. The ashes are loaded to auto trucks from hoppers below the boiler floor, which is above the street grades. The plant is completely equipped to receive coal from any type of coal-carrying boat, from a storage yard adjoining the power house, or from trucks discharging to the conveyor pit. A cable railway operates from the coal storage to the tower and discharges coal to the conveyor.

The cable cars are loaded by a locomotive crane. Messrs. Irwin and Jones, Limited, London House, New London-street, E.C., are the agents for Messrs. C. W. Hunt and Co. for the United Kingdom.

STRENGTH AND INNER STRUCTURE OF MILD STEEL.*

By Professor W. E. DALBY, M.A., B.Sc., F.R.S.,
Associate Member of Council.

IN recent years the study of the inner structure of metals has changed from an interesting research in pure science to an industrial research of profound importance to engineers.

Knowledge of the inner architecture of metals is steadily being accumulated; the effect of heat treatment on the style of the architecture; the true nature of alloys, and the true nature of solidification of metals.

My object in this paper is to illustrate the inner structure of ordinary steel and to show how its strength is correlated with this inner structure.

A metal solidifies by a process of crystallisation. The process starts at innumerable points or nuclei distributed through the mass and transforms the liquid metal surrounding each nucleus into a crystal block. Every individual block is formed of crystal bricks set side by side in regular geometrical formation along axes of growth belonging to the order in which the

FIG. 1. MAGNIFIED 1000 DIAMETERS.

FIG. 2. MAGNIFIED 200 DIAMETERS.

metal crystallises. The outer and visible form of a crystal growth which has grown in freedom shows the geometrical form of the minute crystals of which it is built. But the outer and visible form (visible, however, only in the microscope) of a crystal block grown in a crowd of other growing crystals bears no sort of resemblance to the minute crystals of which it is built. The blocks, microscopic in size, are roughly polygonal; rough boulder-shaped; sharp or blunt edged; or branched like a coral or fir-tree, according to the metal and the circumstances of the solidification and the rate at which heat is abstracted from the cooling metal. Each crystal growth feeds upon an ever-diminishing supply of liquid material in the presence of the gradual approach of the solid walls of the other growing crystals in its neighbourhood. The final shape of a crystal block is thus the result of the arrested growth, first in one direction and then in another direction, owing to the failure of the liquid supply and the obstruction of the crystal walls of its neighbours.

Growth does not start from the primitive points or nuclei in parallel directions, although the axes of growth are at every point geometrically similar in their relative directions. Axes of growth tend to set at right angles to the surfaces across which heat is escaping, but in the interior of a mass the directions of the axes of the crystal blocks are all to appearance quite haphazard.

Iron and steel in the manufactured condition have passed through many processes of reheating, hammering, rolling, remelting and annealing, in consequence of which the crystal blocks of the final structure are not the primitive crystal blocks of solidification but modifications of them, or rather other blocks grown from nuclei formed by the debris of the primitive blocks.

Fig. 1 (above) shows the section of a crystal block as seen in the microscope on a polished and etched section of a piece of good quality Yorkshire iron cut across the direction of rolling. It is polygonal in shape, and measures on the original photographic plate 2.5 in. along the longest diameter, which lies diagonally from the top right to the bottom left. The block is magnified 1,390 times, so that the actual distance across is $\frac{2.5}{1390}$ in. A magnification of 1,390 is equivalent to stretching a yard into just over three-quarters of a mile. The figure is reproduced three-quarters the actual size of the original plate, so that as seen in Fig. 1 the magnification is about 1,000 diameters. The black areas in the figure show cross-sections of thread of slag, which are seen lengthways in Fig. 2. This figure shows the structure of the same material taken along the direction of rolling and magnified only 200 times. The block structure is clearly seen in this photograph.

Mixtures of metals solidify in a similar way. The block structure of brass magnified 40 times is well shown in Fig. 3 on Plate XXVIII; Fig. 4 is an enlargement to 500 times the actual size of a part of the central field of Fig. 3, and shows a block on the surface of which the geometrical shapes of the crystal elements composing it are indicated. These square areas all set in the same direction within the boundaries of the block. The actual size of the block from left to right is $\frac{1}{15}$ in. approximately. Some of the blocks of the structure are, however, larger than this, as will be seen in Fig. 3. One of the largest in this section measures from top to bottom $\frac{1}{15}$ of an inch. The strength of the metal is associated with this block size and diminishes as the blocks grow larger.

Copper and zinc dissolve in one another to form brass, and the blocks in the structure shown in the figures are built of crystals of brass.

All pairs of metals do not mix in this manner. Many metals will not mix with one another at all, and then each metal in the mixture crystallises out separately, the final structure showing a conglomerate built of blocks of two kinds distributed in haphazard manner through the mass of solid metal. Gold and thallium is an example. Gold will not dissolve in thallium nor thallium in gold. They solidify separately from a solution, the gold blocks being built of gold crystals and the thallium blocks of thallium crystals.

Neither the gold nor the thallium blocks are, however, absolutely pure. The gold is slightly contaminated with thallium and the thallium is slightly contaminated with gold. In fact, pairs of metals may be ranged along a scale, beginning with an ideal case of a pair which solidify from solution each in a pure state and ending with an ideal case of a pair which dissolve one another in all proportions and solidify from solution with every crystal brick in every crystal block composed of metal containing the same proportion of the constituent metals as the liquid from which they solidify. Any pair of metals comes somewhere along this scale, but no pair comes exactly at either end.

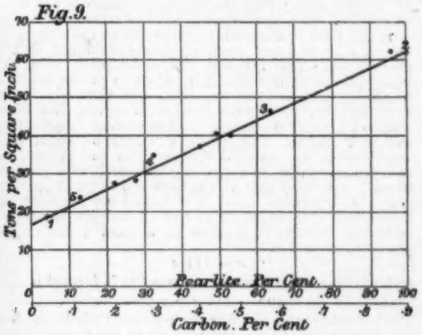
The process of solidification of iron containing carbon is complex, and there is the added complication that the inner structure which exists just below the temperature of complete solidification changes as the temperature falls. The solid crystal blocks rebuild themselves into other shapes as the temperature falls, and, moreover, the final shapes of their blocks and their crystal structure depend upon the rate at which the temperature falls.

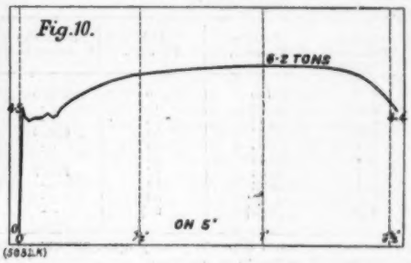
The inner structure of annealed steel as seen in the microscope appears as a conglomerate of iron blocks and pearlite blocks, or a conglomerate of cementite blocks and pearlite blocks. The iron in these structures is usually called ferrite.

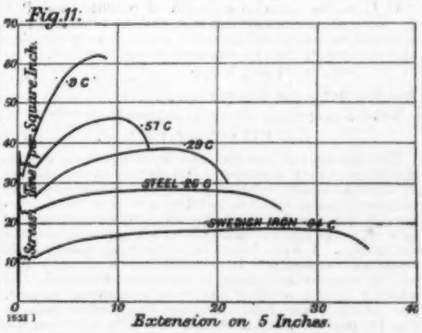
Pearlite is one of the most interesting metallic structures seen in the microscope. The polished and etched surface of a piece of annealed steel usually shows sections of blocks of pearlite. Steel containing about 0.9 per cent. of carbon is built of blocks of pearlite and nothing else.

Pearlite is itself a conglomerate constructed of alternating sheets of iron and cementite. Cementite is the chemical compound of iron and carbon having the definite formula Fe_3C. Thin sheets of iron with thin sheets of cementite between them, packed closely together, 60,000 to the inch, form the substance of a pearlite block, and these packed sheets are bent in the pack into the shapes which suggest that the final forms of the blocks seen in the microscope have been developed against a complicated play of internal molecular forces. Sections of these pearlite blocks seen in the microscope resemble certain sections of stratified rocks seen on a grand scale.

Fig. 5 (Plate XXVIII) shows the structure of a piece of steel built wholly of pearlite blocks. It contains 0.9 per cent. of carbon. The section plane cuts the curving sheets of the structure at all angles. Where it cuts the sheets at right angles they appear closely packed and of regular thickness, but this appearance merges into one of overlapping plates and scales as the sheets get more and more inclined to the section plane. The individual blocks of the structure can be made out, but their boundaries are rather indefinite. The large central group of blocks almost suggests the shape of an heraldic bird. From the tip of the tail vertically to the top of the head the distance is about 2.5 in. on the figure. The structure is magnified 1,000 times, so that the actual distance is about $\frac{2.5}{1000}$ in. At places where the sheets are most closely packed it is reasonable to suppose that they are cut square across, so that the actual thickness of a pair of them can be measured. The average thickness of a pair measured on the figure is $\frac{1}{75}$ in. Therefore the actual thickness of a sheet







of iron and a sheet of cementite next to it is of the order $\frac{1}{75 \times 75}$ in.

The block structure is better seen in Fig. 6, Plate XXVIII, which shows a section of 0.57 carbon steel magnified 1,000 times. There is not enough carbon present to convert the whole of the iron into pearlite blocks. As much of it is converted as possible, and then the iron left over appears as an element in the structure, so that what is seen in the microscope is a conglomerate structure of pearlite blocks and free iron blocks, though the etching has not been carried far enough to bring out the boundaries of the free iron blocks. In some places single blocks of pearlite are seen; in other places groups of two and three blocks. The distribution of the pearlite blocks is uniform and shows good material. The texture of the pearlite is rather finer than that measured in Fig. 5, being of the order $\frac{1}{75 \times 75}$ of an inch.

In the section of a piece of 0.29 carbon steel shown in Fig. 7, magnified 1,000 times, a pearlite block of large size is seen isolated. Its greatest length is $\frac{1}{75}$ of an inch, and the alternating sheets of iron and cementite show great uniformity and straightness. It looks as though the section caught the block squarely across the direction of the sheets. The thickness of a pair of sheets is rather more than in the previous example. The structures in Fig. 5, 6 and 7 are all of them of

* Paper read before the Institution of Naval Architects, March 28, 1917.

material which has been worked and treated. Fig. 8 shows the structure of a section of a piece of pig-iron. The magnification is 500. The area shown in the figure is in actual size about $\frac{1}{2000}$ of a square inch. It is seen that this part of the metal is constructed entirely of blocks of pearlite. The shapes of these blocks indicate, however, the shapes of the primitive crystals formed on solidification, because the metal has never been melted nor treated after solidification. The pearlite appears to be rather coarser than that seen in the steel structure illustrated in Figs. 5, 6 and 7. The closest packing in the area measures about 30,000 pairs of sheets to the inch. This metal is the first product of the blast furnace, and yet it exhibits amongst its structural elements pearlite blocks, the building material of fine steel. Pig-iron shows other kinds of blocks in other areas, and I will return to the general structure of this iron presently.

The chemical formula for cementite, namely Fe_3C, shows that cementite consists of 168 parts by weight of iron and 12 parts by weight of carbon, corresponding to 1 part of carbon and 14 parts of iron in 15 parts of cementite. Therefore 0.9 part of carbon form with 12.6 parts of iron 13.5 parts of cementite. Analysis of pearlite shows that the blocks contain 0.9 per cent. of carbon. It follows that a pearlite block consists of 13.5 per cent. of cementite distributed in the cementite sheets and 86.5 per cent. of iron distributed in the iron sheets. This involves the assumption that the whole of the carbon found by analysis in the pearlite blocks is used to form cementite and that none of it is in the iron. It is quite possible, however, that there may be a small proportion of the carbon dissolved in the iron sheets. The quantity would be small and would make no material difference to the proportion of iron and cementite composing the sheets of a pearlite block. Assuming that all the carbon present in pearlite is in the cementite sheets, and taking 0.9 per cent. as the carbon corresponding to the all pearlite structure, x, the percentage of pearlite in a steel containing c per cent. of carbon is

$$x = 111\ c$$

and the iron left over after the pearlite is formed is

$$100 - 111\ c \text{ per cent.}$$

The following table exhibits to the nearest whole number the proportion of iron and pearlite in steel for various percentages of carbon :—

Carbon Per cent.	Pearlite Per cent.	Iron Per cent.	Structure shown in
0.9	100	0	Fig. 5
0.8	89	11	—
0.7	78	22	—
0.6	67	33	Fig. 6
0.5	55	45	—
0.4	44	56	—
0.3	33	67	Fig. 7
0.2	22	78	—
0.1	11	89	—
0.05	5½	94½	—

The strength of steel depends jointly upon the strength of iron and the strength of pearlite.

If f_p is the ultimate strength of pearlite, and P is the percentage of pearlite present, and if f_i is the ultimate strength of pure iron (ferrite), and I the percentage of iron present, then f_s, the strength of the steel, is—

$$100\ f_s = f_p\,\mathrm{P} + f_i\,\mathrm{I} \quad . \quad . \quad . \quad (1)$$

But $\mathrm{P} = 111\ c$ and $\mathrm{I} = 100 - 111\ c$.

Substituting these values (1) reduces to

$$f_s = 1.11\ c\,(f_p - f_i) + f_i \quad . \quad . \quad (2)$$

The strength of pearlite can be found from experiments on steels containing 0.9 per cent. of carbon. From experiments which I have made on steels of this composition and with the pearlite structure fully developed I find that f_p is probably about 62 tons per square inch with the normal manganese, phosphorus, sulphur and silicon. I have found, however, that considerable variation in strength is possible for steel with this carbon content according to its inner structure, *i.e.*, whether or not pearlite has been completely formed. The curve of the load extension diagram is seen in Fig. 11, page 319, and it is strikingly different from the forms of the curves for steels with a carbon content up to 0.7 per cent. This difference in form suggests that there is some discontinuity in the properties of the material in the region of this particular mixture—the eutectic mixture as it is called. This is a point which requires further investigation.

It is more difficult to find a true value of the ultimate strength of pure iron. The commercial pure irons contain small quantities of carbon. Some irons contain as much carbon as the mild steels, but I have never been able to find any pearlite in such irons although they contain carbon in quantities which in steels are sufficient to show pearlite. The carbon seems to exist in iron in a different form from that in which it exists in steel. The difference in the manufacturing processes may account for this, because it must not be forgotten that iron is produced by processes which do not involve the melting of the iron at any stage. On the other hand, steel is made from a re-melt of the pig-iron produced in the blast furnace, and carbon is added to it in the bath in the form of ferro-manganese. Sir Robert Hadfield gave me some very pure Swedish iron containing only 0.04 per cent. of carbon, and the average of six tests on this material gave an ultimate strength of 18.8 tons per square inch. From the diagram immediately to be described, it is deduced from this and other data that the ultimate strength of pure iron is about 16 tons per square inch.

The ultimate strengths of a series of steels are plotted against their respective pearlite contents in Fig. 9. The scale of carbon content is added below the pearlite scale. Point 1 is the ultimate strength of good Swedish iron containing 0.04 per cent. of carbon. Point 2 corresponds to a steel containing 0.9 per cent. of carbon, and its structure is shown in Fig. 5 above. The line joining points 1 and 2 cuts the vertical axis through the origin at 16, indicating that the ultimate strength of carbon free iron which has been worked is probably about 16 tons per square inch. The ultimate strength of the 0.57 carbon steel shown in Fig. 6 is plotted in point 3, and point 4 corresponds to the structure shown in Fig. 7. Other points are plotted on the diagram showing the results of tests made on annealed steels of known carbon contents. Variations of ultimate strength from any linear law are to be expected owing to the effects of the various impurities Mn, Si, S and P, but the nearness of the points to the line suggests that the line fairly represents the strength of steel in terms of the pearlite content at any rate to a first approximation.

Introducing the values therefore—

$f_i = 16$ tons per square inch.
$f_p = 62$ tons per square inch.

equation (2) above becomes—

$$f_s = 1.11\ c\,(62 - 16) + 16 = 51\ c + 16 \quad (3)$$

This relation therefore represents the ultimate strength of good commercial steel of normal quality after annealing to allow the pearlite to form. Overstrained steels or steels containing excess of any of the ordinary impurities would show departures from the general law.

Load-extension diagrams of all of the steels represented on the diagram have been taken with the apparatus I had the honour to describe and exhibit at the Spring Meeting in 1912.*

Fig. 10, page 319, is a facsimile of the diagram corresponding to point 5, Fig. 9, and shows well the characteristic curve for steel, namely, an elastic part joined to a plastic part by an irregular link beginning with a definite drop from the breaking-down load.

A selected number of these load-extension diagrams have been reduced to a common scale of ultimate stress and elongation for the sake of comparison and are plotted over one another in Fig. 11. The progressive decrease of ductility with increase of strength brought about by increasing proportions of pearlite in the structure is well exhibited by these curves.

Figs. 12, 13, 14, Plate XXVIII, show the different inner structures of a piece of the same steel brought about by different rates of cooling. The steel sample, the structure of which is seen in Fig. 12, was heated to 900 deg. C. and quenched rapidly in water; the resulting structure is seen in Fig. 13. It was then heated again to 900 deg. C. and cooled slowly; the original pearlite structure was recovered, as will be seen in Fig. 14. The original pearlite structure seen in Fig. 12 is finer in texture and the pearlite blocks are smaller than in the recovered pearlite structure seen in Fig. 14. The structure Fig. 12 was formed in the bar before the small cube, which was afterwards polished and etched, was cut off. The annealed structure Fig. 14 was produced by heating and slowly cooling this small cube. The circumstances of the formation of the two structures were therefore different both as regards the internal pressures produced by cooling and the configuration and slope of the lines of heat flow.

As mentioned above, the pearlite structure of pig-iron shown in Fig. 8, Plate XXVIII, is not the only structure in the metal. As the field of view is changed other structures of remarkable beauty appear. A general view of a polished and etched surface of a piece of Cleveland mottled pig-iron, under the moderate magnification of 62 diameters, is shown in Fig. 15, Plate XXX, and seen in the microscope reminds one irresistibly of mountain scenery. Gleaming white glaciers appear to be making their way between dark jagged rocks and boulders and jutting peninsulas, and the glaciers themselves appear to be lightly covered in places with a network of glittering crystals.

The glaciers are really gleaming crystals of cementite, and the dark rocky masses are seen to be a structure built of blocks of pearlite, of which Fig. 8 is typical, with here and there black patches where either slag or graphite has been detached by the polishing process. The crystal network is a mixture of iron-carbon and phosphorus in the most fusible proportion.

Figs. 16, 17, 18, 19, 20, 21, 22, Plate XXX, seen around the composite Fig. 15 show areas of this general figure to an enlarged scale. Pearlite structures are seen in all of the figures.

These structures are not all formed at one temperature as the metal cools; neither are they dissolved into liquid iron at one temperature. A remarkable series of changes takes place in the solid before the metal is actually melted. Imagine that a piece of the metal can be placed in a crucible in circumstances which enables its inner structure to be projected as a picture on a screen so that we can look at the picture during the process of heating and liquefaction. We should see one picture dissolve into another as the temperature increased, until finally we should look at the picture of a structureless liquid consisting of melted iron with carbon dissolved in it. If we could in reality look at such pictures many questions of controversy might be settled, but the researches of Dr. Stead enable us to form a very good idea of the pictures we should see.

The first picture on the screen would be like Fig. 15, and this would remain until the temperature reached about 725 deg. C., when the pearlite would fade away. The sheets of cementite would, though solid, dissolve into the sheets of solid iron and produce a homogeneous mixture of cementite and iron; the mixture called austenite. The geography of the picture would remain the same, but from this point onwards the cementite crystals (seen clearly in Fig. 16) round about the grey masses of austenite would in part be absorbed into them, because iron is able to dissolve increasing quantities of cementite as the temperature rises. At about 953 deg. C. the iron-phosphorus-carbon mixture (seen plainly in Fig. 16) would melt and the temperature rising there would be pockets of liquid material distributed through the still solid mass of austenite and cementite crystals. At about 1,100 deg. C. the cement crystals would melt and the austenite would begin to melt, and would go on melting with rising temperature until the mass was wholly liquid.

If now the temperature were allowed to fall again the operations would take place in the reverse order. First crystals of the solution of iron and cementite would grow in the fir-tree form, and not until the temperature had fallen to about 1,100 deg. C. would the cementite begin to form crystals on its own account. The cooling mass would then appear as a conglomerate of fir-tree blocks or crystallites, the crystal elements of which are formed of a solution of cementite in iron austenite, and separate crystals of pure cementite, and these would by now be solid; but distributed through the solid mass would be liquid pockets of the iron-phosphorus-carbon mixture about to form the crystal net-like structure when the temperature has fallen to 953 deg. C. The picture would now show a mass completely solid; but probably much change in the geography would be noticed as the mass cooled, because the cool structure exhibits the crushed and distorted remains of the fir-tree crystallites, and they appear to have been subject to great pressure during the cooling process. A cursory examination of the enlarged photographs round Fig. 15 will show how the regular growth which is indicated by the remains of an uncrushed crystallite enmeshed in crystals of cementite is distorted in the dark areas into blocks of irregular form. Finally at 725 deg. C. we may assume that the geography has settled down to its final shape, and then, given time and patience, all the dark areas would be seen to change into the laminated structure of pearlite.

Each one of these changes is accompanied by heat evolution, and it is this heat evolution which enables the changes to be traced. The process of identifying changes of structure with heat evolution is a laborious one, as will be understood from the Reports of the Alloys Research Committee of the Institution of Mechanical Engineers, reports which are no doubt familiar in a general way to most of us. Professor Carpenter has made extensive researches into the matter, particularly in relation to iron and steel, and has obtained data for the construction of the temperature-concentration diagram for carbon in iron. This diagram is exceedingly useful to us as users of steel, and furnishes a key to many apparently disconnected workshop processes which have been derived from experience, and which have been tested by experience, but are none the less founded on and connected by the underlying bonds of pure science. Professor Carpenter has kindly promised to give us a paper next year on the diagram which his own researches have done so much to establish.

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*"Load-extension Diagrams obtained Photographically with an Automatic Self-contained Optical Load-extension Indicator."—Trans. I.N.A., 1912. ENGINEERING, April 12, 1912.

MINERAL RESOURCES DEVELOPMENT BRANCH OF THE MINISTRY OF MUNITIONS.—A new branch of the Ministry of Munitions has been established under Sir Lionel Phillips, Bart., as Controller, to deal with the examination and development of such mineral properties (other than coal or iron ore) in the United Kingdom as are considered likely to be of special value for the purposes of the war. The Minister of Munitions has appointed the following gentlemen to act as an Advisory Committee on the development of mineral resources: Sir Lionel Phillips, Bart. (chairman), Mr. F. J. Allan, Mr. C. W. Fielding, Mr. R. J. Frecheville, Professor F. W. Harbord, F.I.C., Assoc.R.S.M., Mr. F. Merricks, Sir Harry Ross Skinner, Dr. A. Strahan, LL.D., F.R.S. (representing the Geological Survey), Mr. Edgar Taylor, together with a representative to be nominated by the Board of Trade.

RESTRICTIONS TO TRADE.—The Board of Trade announce that in view of misunderstandings that have arisen with reference to the meaning of the Order as to priority issued by the Ministry of Munitions of War on March 8, 1917, and particularly to paragraph (*c*) of the definition of Class B certificates given in the first schedule thereof, the Board of Trade announce that manufacturers in the industries affected are free to carry on their ordinary commercial business as at present unless and until they receive any orders accompanied by priority certificates A or B. So far as relates to export Orders, it is not the intention of the Board of Trade to exercise their power of certification as a rule by dealing with particular orders, but by the issue of an official Order specifying any industry in which they consider that production for export should have priority over production for home consumption, and also specifying the classes of orders to which for this purpose priority must be given, subject to any limitations or conditions which may be laid down and to the issue of a certificate by a Government Department or other authority controlling any necessary materials that such materials can be spared. Any such official Order that may be issued will be general in character, and it will be unnecessary for applications to be made to the Board of Trade each time an exporter desires to secure priority.

THE METRIC SYSTEM.

To the Editor of Engineering.

SIR,—I read your leader in the current issue of your paper with considerable disappointment, since it appears to me that you seek to confine the issue in this country to cost of change only. I attended the meeting at the Institution of Civil Engineers, and the one thing which struck me more than anything else was the atmosphere of unreality in the discussion. Each speaker was allotted 5 minutes; and the audience seemed to be more impressed by the few "humorous" remarks made than by any argument. Indeed, as another member said to me, I think a large majority of the engineers present believed the metric system would never be adopted in this country, and that it was useless to discuss a purely academic subject. Those actually interested for or against the metric system, or in what the lecturer thoughtfully called "freak" metres, attended the meeting, and the others (the great majority) simply stayed away! In the circumstances discussion was futile, and some would-be speakers walked out before the proceedings terminated!

If you desire to raise a real discussion, I fear you will have to publish a special supplement for a few weeks. There will not be any room in your usual issue in the present circumstances. And even then I doubt whether your supplement would be of much value, since so many of our best and most representative engineers are engaged in the war and have no time for other matters.

All I want to point out now is:—

(*a*) A discussion which took no notice of the 90 per cent. of humanity who do not want decimals, but earnestly desire to be allowed to continue to employ vulgar fractions, would be incomplete.

(*b*) A discussion which might omit such important items as the effect of a change upon the small dealers and the small consumers would be unjust.

(*c*) A discussion which failed to consider the latest discovery in weights and measures, and the fact that the *Encyclopædia Britannica*, vol. xxiv, page 484, paragraph 13.3, confirms it, would be no discussion at all. We already possess serviceable decimal weights, measures and currency, and employ the 5-link or 39.6-in. Belgic yard (our "British" metre) in practically all our units. You know the scientific rule: one coincidence, &c.? Here we have over a score of coincidences. What have your readers to say to the matter?

I am, Sir, yours, &c.,
E. A. W. PHILLIPS, M.Inst.C.E.

Rawdon House, 4, Aymer-road, Hove, April 2, 1917.

To the Editor of Engineering.

SIR,—You invite a discussion on the subject raised by Mr. Allcock's lecture at the Institute of Civil Engineers last week, and in doing so it is to be hoped that you will exercise your veto more drastically than the president of the Institution did, and keep out special pleaders from either side. I venture to think that there is very little to say on the subject, and that what remains to be said must be expressed mainly by the manufacturers, who are, on the whole, those chiefly interested in any change of units.

Engineers are of necessity "decimal" men; they have been so by *compulsion*, because "*time is money*." There is probably no other profession in which the slide rule is so universally used and appreciated. The majority, possibly, of those who advocate the decimal notation and its advantages are very far behind the engineer in its employment. It appears to me, therefore, to be "thrashing a head horse" to urge upon engineers the importance of a decimal system, as was done at the Institution last week, and just so much lost time.

There is only one other point left, viz., the choice of the unit. In discussing this point the shops may be dismissed at the outset, so far as regards their capacity for employing either the *inch* or *centimetre* as the unit of length. The production of a bar of a certain definite length is just as *easy* and as *difficult* on either system of units, and I have never been able to grasp the basis for any arguments in favour of the one or the other unit. Take at random a machine and measure a journal, a bearing, &c., and the chances are very remote that either could have its dimensions expressed exactly in any existing system of units. It is common knowledge that a shaft turned to, say, 2 *inches* nominal diameter will actually measure 2 + the tolerance inches, and work quite as satisfactorily as if it were exactly 2 in. Moreover, the exact 2 in., if achieved, would only hold at one temperature, which could not be maintained continuously.

In addition, the only method of manufacturing parts in quantity is by means of jigs and limit gauges, and how can it influence facility of workmanship that the gauges employed actually measure 1.0015 in. and 0.9985 in., or that the legends upon the gauges read 2.5438 cm. and 2.5184 cm., both being equivalent measures of the same length. Remember that it *is* the same gauge that is being used. Who would be so bold as to say that the shop's output would differ in any way if the gauge had only a reference number impressed upon it, nothing being said concerning its actual size or the units employed by the designer? It is quite evident that a change in the unit or subdivision employed would not create any difficulty in the shops.

It will be somewhat different as regards existing standards of end measures (I do not mean existing limit gauges; these would only need re-marking), which would be rendered comparatively useless by a compulsory change of units. But so far as my experience goes, I feel that immediately before the war there were comparatively very few shops that possessed any "standards" of reference other than a few plug and ring gauges and steel rules. How many (per cent.) mechanics can read a micrometer or are accustomed to use one with facility?

The point that is being pressed most insistently now is the possibility of "foreign trade" developments. Here, again, the question appears to me to be one essentially for the manufacturers. Hitherto our shops have been run with conspicuous success on the "inch" unit, but manufacturers, so soon as they find it a better investment, will adopt without any compulsion the centimetre as their unit—there is nothing at present to prevent them doing so. The necessity to produce a dividend is the great *compelling* factor that is required to ensure the adoption of the centimetre. It is said that manufacturers in the past have not studied the foreign customer's peculiarities, but I think that is in the main due to the fact that their shops have found work up to their full capacity in the past, and it is self-evident that money spent in cultivating additional trade would be wasted, because it could not be executed if obtained. Our export trade may have to be enormously increased immediately after the war, in order to meet our financial undertakings; if this prove to be the case (and it is very probable), no doubt our engineers will show themselves fully capable of meeting the situation as soon as it occurs. Is not the appeal to the profession a proof of the dim consciousness that nothing will be done effectually without their help?

For these reasons, and others, it is evident that this question of change of unit of length is one that concerns the manufacturers chiefly; it is up to them, therefore, to consider the matter carefully before the theorists carry their notions in spite of them. As regards the scientific world, they, in order to reduce the work of comparison of results obtained by them in all parts of the world, have decided in favour of the centimetre already as the international unit, and have so employed it exclusively for many years. The manufacturers' problem may not be quite the same as that of the investigator, and it remains for them to say what differences exist and their nature. I venture to think that the statement of the costs made by Mr. Aspinall will not carry much weight and should have been left unsaid. I mean the cost of repainting the tare weights of the wagons, &c., for whilst in the aggregate the sum he mentioned sounded heavy, Mr. Aspinall probably will allow that these trucks require repainting at times, and the tare weights in the new units would not cost any more than in the old.

Yours very truly,
G. JAMES WELLS.

Mile End-road, E., April 3, 1917.

METRIC BILL, 1917.

To the Editor of Engineering.

SIR,—The first part of the letter appearing on page 308 of your issue of the 30th ult. is very interesting, because when I met Mr. Barton recently (at a meeting composed very largely of metric madvocates), some people got the impression that I had no "friends" in the metrick-wickian sense.

Mr. Barton evidently appreciates to some extent the argument as to "persistence." This is, however, no new point; it was put forward by the Brown and Sharpe Company in 1902 in a letter to a Government committee in the United States of America, wherein they stated that "measures of length are tied irrevocably to the past," *i.e.*, by physical, not sentimental ties.

My query as to bolts is not fully answered by Mr. Barton. What is a ¾ Whitworth bolt under the new *régime*? One of the great arguments for the change of standards is that all old-fashioned anomalies like "quarters" of wheat, &c., will be dispensed with, and everything based upon one system, and yet here at the very outset we are told to speak of ¾ bolts. Nor does Mr. Barton tell us what the pitch of the threads will be!

The reference to questionnaires is most unfortunate for Mr. Barton. The Decimal Association arranged with a circular-addressing agency to send out numerous inquiries on this subject, enclosing a printed slip for the reply, but, curiously this slip only provided for replies in the affirmative! Apparently about thirty people had the hardihood specially to indicate their disapproval, and the probability is that they would quite outweigh the others if consideration were given to their experience as makers, as distinguished from computers and talkers.

If a circular were sent to all the schoolboys in a town asking whether they were in favour of an Act of Parliament permitting orchards to be raided during the summer holidays their votes would far outnumber those of the owners of the orchards but the following year there would be no orchards.

Your leading article on page 301 asks for this discussion to be raised to a higher level, and I commend to such metric enthusiasts as may have the welfare of the British engineering trade really at heart the article by Dr. A. E. Kennelly in the *Scientific Monthly* for March, 1917, wherein he makes suggestions for the *gradual* adoption of the metric system in foreign trade and Government work without the exercise of *compulsion*, always assuming the change would be beneficial eventually.

I remain, yours truly,
DANIEL ADAMSON.

Hyde, Cheshire, April 2, 1917.

TRADING WITH THE ENEMY ACT.—The Controller of the Foreign Trade Department has sent us a copy of a new list (No. 23) of additions to the Statutory List of firms of enemy nationality or enemy association with whom persons in the United Kingdom are forbidden to trade. Copies of this list can be obtained from the Superintendent of Publications, H.M. Stationery Office, Imperial House, Kingsway, W.C.

MARINE APPLICATIONS OF REDUCTION GEARS OF FLOATING FRAME TYPE.*†

By Mr. JOHN H. MACALPINE.

THE present paper may be considered to be a sequel to a long article by the author "On Reduction Gears," which appeared in ENGINEERING from May 5 to June 16, 1916; and also to a leader in ENGINEERING of September 17, 1909. These articles taken together deal very fully with the design, theory, and performance of reduction gears of the floating frame type as originally produced by the late Admiral Geo. W. Melville, U.S.N., and the author, known as the "I" beam type. In ENGINEERING of November 17, 1911, there is shown a variety introduced by the late Mr. Geo. Westinghouse, known as the hydraulic floating frame type, which will also be referred to. For a full discussion of the subject the reader is referred to these articles.

The bearings of a pinion and gear are, in most machines, supported very rigidly in a heavy framework or bedplate. Such gears will here be referred to as "rigid gears." Reduction gears designed thus had been considerably experimented with to transmit the power of the turbine, but before Admiral Melville and the author took the question up in 1904 the solution of the problem of gearing for the turbine seems to have been despaired of except for very small powers.

Assuming that the teeth could be cut almost perfectly in a modern gear-cutting machine, it appeared evident to us that one important condition was left which, for the best result, it was essential to remove—the slightest error of alignment of the pinion, which is long in proportion to its diameter, would produce great inequality of distribution of pressure along the teeth. The method we adopted for freeing the design from delicacy of alignment was very simple. It consisted in mounting the pinion bearings in a very stiff frame, supported near the middle of its length by the bedplate, but (where the teeth are not in mesh) very free to move about an axis transverse to the axes of the gear and pinion. Thus the exact position of the pinion axis at any time is in part determined by the interaction of the teeth. Great equality of distribution of tooth pressure results. The figures to be given will illustrate this construction, which will now be referred to very briefly as it is well known. The discussion given in the articles referred to above need not be repeated here, but the most important conclusions reached, particularly in the long article of last year, may be briefly given:—

1. A floating frame gear will operate perfectly with the pinion sensibly out of line, and therefore the great difficulty of rigid gears—bad distribution of tooth pressure from minute errors of alignment—vanishes.

2. That the floating frame corrects from one-half to two-thirds of the effect of torsional yield of the pinion.

3. That the performance of gears of any design should be judged by the value of the "power constant" ‡ it will safely bear.

4. From published data for rigid gears, and from those given here for floating frame gears, it is clear that, as anticipated, the power constant at which the gears are usually run is much higher in the case of floating frame gears than of rigid gears.

The power constant for rigid gears appears usually to be not greater than 2, while 3.5 and 4 are perfectly safe values for floating frame gears. Indeed, in the 12-hour full-power trial of the United States collier Neptune the average power constant was 5.22. It has been in service for over one and a-half years, and is frequently used at full power.

5. Comparing gears of different types, with a given ratio of reduction, a rise in the safe power constant quickly reduces the weight per hourse-power. This is illustrated in last year's article by the examination of a number of marine installations, and it is there shown that the higher power constant of the floating frame gear effects a marked reduction of weight over the rigid gear. Or, for the same weight of machinery, a greater ratio of reduction may be effected, allowing of a slower rotation and higher efficiency of propeller, or of a faster, smaller, and more efficient turbine.

These are the principal conclusions, although there are others of some importance and many details to which I do not refer here.

I will now illustrate and describe two marine installations: the first of a slow oil-tank, single-screw steamship, with double reduction; the second, a faster passenger and freight twin-screw steamer with single reduction.

Oil-Tank Steamship.—This ship is being built by the Chester Shipbuilding Company, Limited. It is one of 45 freight ships of about the same power for which the Westinghouse Machine Company are building duplicate or nearly duplicate machinery.

Length	401 ft.
Beam	54 ft.
Draught	25 ft. 9 in.
Displacement	12,650 tons
Cargo capacity	9,000 tons
Full speed, loaded	11.5 knots
Full power	2,900 S.H.P.
Turbines	3,860 R.P.M.
Propeller...	75 R.P.M.

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* Paper read at the Institution of Naval Architects, March 29, 1917.

† Proof uncorrected by author.

‡ Power constant $= \frac{1000\ P}{D^3\ R}$,

where P = horse-power transmitted,
D = the diameter of pinion in inches,
R = revolutions per minute of pinion.

The arrangement is sufficiently shown by the plan, Fig. 1, Plate XXIX. There is a cross-compound turbine, the high-pressure and low-pressure parts each actuating a separate single-pinion first reduction gear which reduce the revolutions per minute from 3,860 to 483. There is one second reduction gear with two pinions, each first reduction gear actuating one of these, and the large gear driving the propeller shaft at 75 r.p.m. The turbines are aft of the gears. This arrangement allows the propeller shaft to be drawn inboard without disturbing the turbines or gears.

The ahead high-pressure turbine is composed of a two-row, high-pressure, impulse wheel followed by reaction blading carried on a drum. The ahead low-pressure turbine has only reaction blading. Each of these turbine casings contains an astern turbine consisting of a two-row impulse wheel. The high-pressure and low-pressure turbines are usually operated as a cross-compound turbine; or, by suitable pipe and valve connections, either ahead or astern turbine elements can be operated singly and exhaust direct to the condenser, in case of emergency. The astern turbines can develop over 60 per cent. of the full ahead power with the same flow of steam.

With dry saturated steam of 180 lb. per square inch at the high-pressure inlet and 28.5 in. vacuum (30 in. barometer), the guaranteed consumption of the turbines is 11.50 lb. of water per shaft horse-power hour. Various valves, &c., for regulating the turbines are indicated in Fig. 1, but these need not be described.

The first reduction gear is shown in Figs. 2 to 5, Plate XXIX. The pinion is driven through a flexible coupling, allowing end play, carried on the right-hand end, Figs. 2 and 5, of a flexible shaft B passing through the pinion and fastened to it at the left-hand end. The teeth are cut in right and left hand helices, as is seen clearly in the second reduction gear at the left-hand side of Fig. 5. The pinion has three bearings held in a very stiff floating frame C.

When it is not desired to measure the power being transmitted the long bolts D, Figs. 4 and 5, Plate XXIX, are screwed down and fasten the floating frame to the bedplate or housing, but still leave it sufficiently free, so that any inequality of moment of the tooth pressures on the right and left-hand helices about the centre of length of the floating frame would cause the frame to tip about a transverse axis and restore this equality. For a full analysis of this see the articles of 1909 and 1916 in ENGINEERING, referred to above.

When it is desired to measure the horse-power when running ahead the lower valve G, Figs. 4 and 5, Plate XXIX, is opened, which allows oil to flow from the lower side of the centre pinion bearing, at considerable pressure, to the hydraulic cylinder F, through the passages shown. The bolts D having been screwed back slightly the pressure in F will cause the floating frame to rise about the fulcrum E. This slight rise is indicated through a finger H, actuating a multiplying mechanism which is too small to show in the figure. A pressure gauge indicates the oil pressure in F. As the weight of the floating frame, pinion, &c., are known, these can be deducted from the total upward pressure, and the remainder gives the total downward pressure of the pinion on its bearings. From this and the revolutions of the pinion the horse-power transmitted by the gear can, obviously, be at once calculated. Similarly, when going astern, the power may be measured by means of the upper hydraulic cyclinder F.

Thus this floating frame embodies the features of the original I-beam frame and the dynamometer of the hydraulic floating frame explained in the 1911 article in ENGINEERING, referred to in the first paragraph of the present paper. Although many of these hydraulic floating frames have been built and have acted most satisfactorily for all land work and much of the marine work, the Westinghouse Machine Company have returned to the original and simpler I-beam type. The only changes are:—

First, originally the flexibility was provided by the web of separate I-beams. This construction is still retained except in the smaller gears. In these the web is cast on to the lower half of the floating frame as shown in the second reduction, Fig. 8, Plate XXIX.

Second, the dynamometer is introduced for marine work. Of course, in double reduction installations this is only required in the first reduction gear, as shown for this ship.

The floating frame is deprived of freedom of rotation about a vertical axis by two horizontal struts near the ends, the position of one being shown at I, Fig. 2. They are also seen in Fig. 5. Without these the floating frame would have slight instability about this axis. The rims of the large gear A, Fig. 5, are rolled, though cast-steel rims have also been used with perfect success. These are mounted on an iron casting and the centre shaft is of forged steel.

The second reduction gears, Figs. 5 to 8, Plate XXIX, call for no further remark. A Kingsbury thrust (known in Britain as the Michel) is mounted at T, the forward end of the shaft.

	First Reduction Gear.	Second Reduction Gear.
Power per pinion ...	... 1,450 h.p.	1,450 h.p.
Pitch diameter of pinion	... 5.114 in.	10.228 in.
R.P.M. of pinion ...	... 3,860	483
Power constant ...	... 2.81	2.81

These gears are standard, designed for a maximum rating of 3,400 h.p., with a power constant of 3.3.

The lubricating oil is pumped from a drain tank in the bottom of the ship by a rotary pump, L, Fig. 3, which discharges it into an overhead gravity tank (fitted with strainers) at a height which will give a pressure of about 5 lb. per square inch to the oil at the discharge to the bearings and teeth. After leaving the gravity tank it passes through a suface water cooler and thence discharges to the sides of the bearings, where the bearing pressure is zero, and to the teeth as they are coming into mesh, so that it cannot be thrown out by the high centrifugal forces. If the level of the oil in the gravity tank should fall a short distance, still leaving a full supply for 10 or 15 minutes, an electric bell rings, warning the engineer to start an auxiliary oil pump. When the turbines are running slowly or stopped the oil is circulated by this pump.

The condenser circulating pump is driven by a geared turbine. The vacuum in the condenser is maintained by a Westinghouse Leblanc air ejector, and the

REDUCTION GEAR OF FLOATING FRAME TYPE.

Fig. 9. ARRANGEMENT OF MACHINERY AND MAIN STEAM PIPES FOR 10,000 S.H.P. TURBINES AND REDUCTION GEARS.

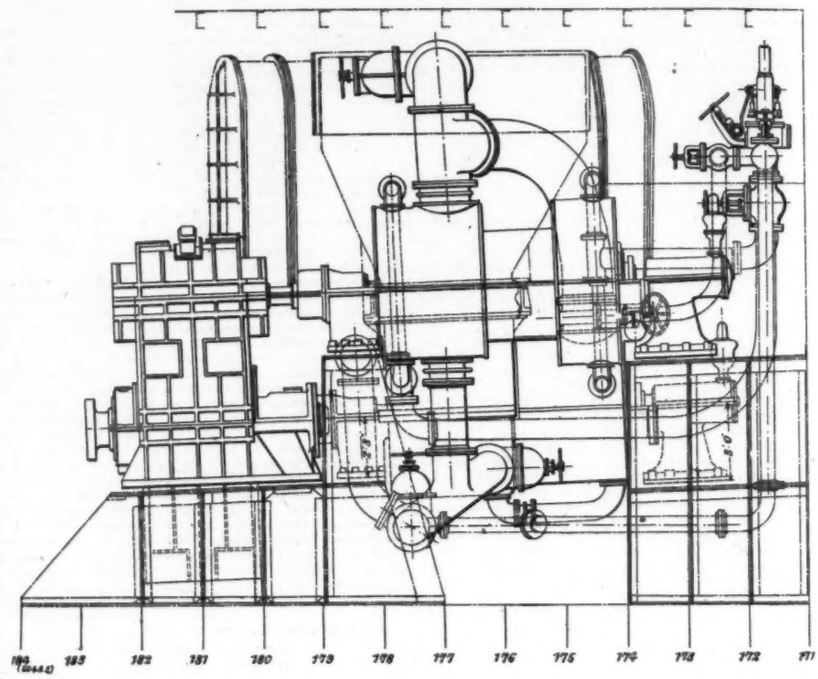
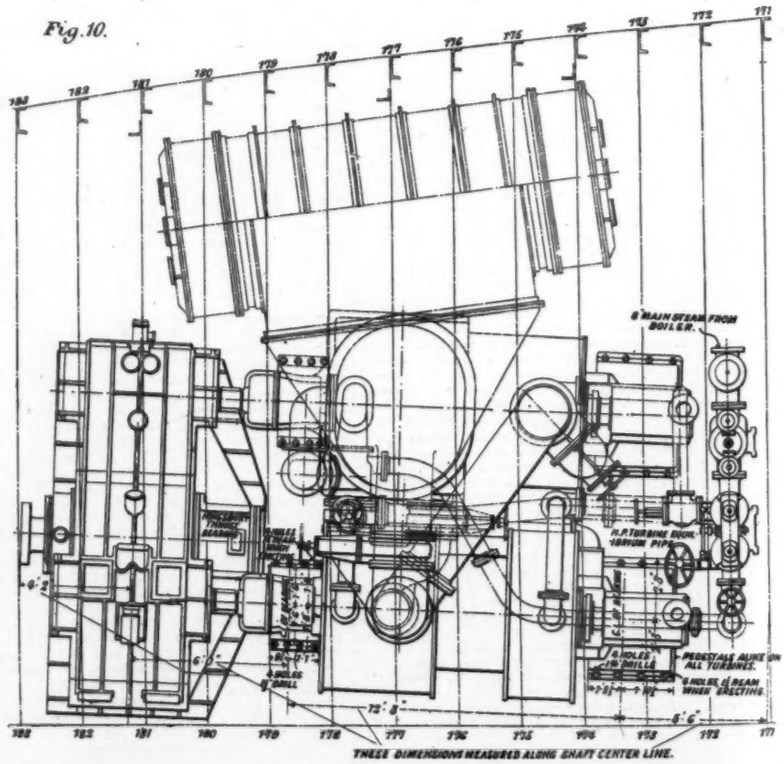
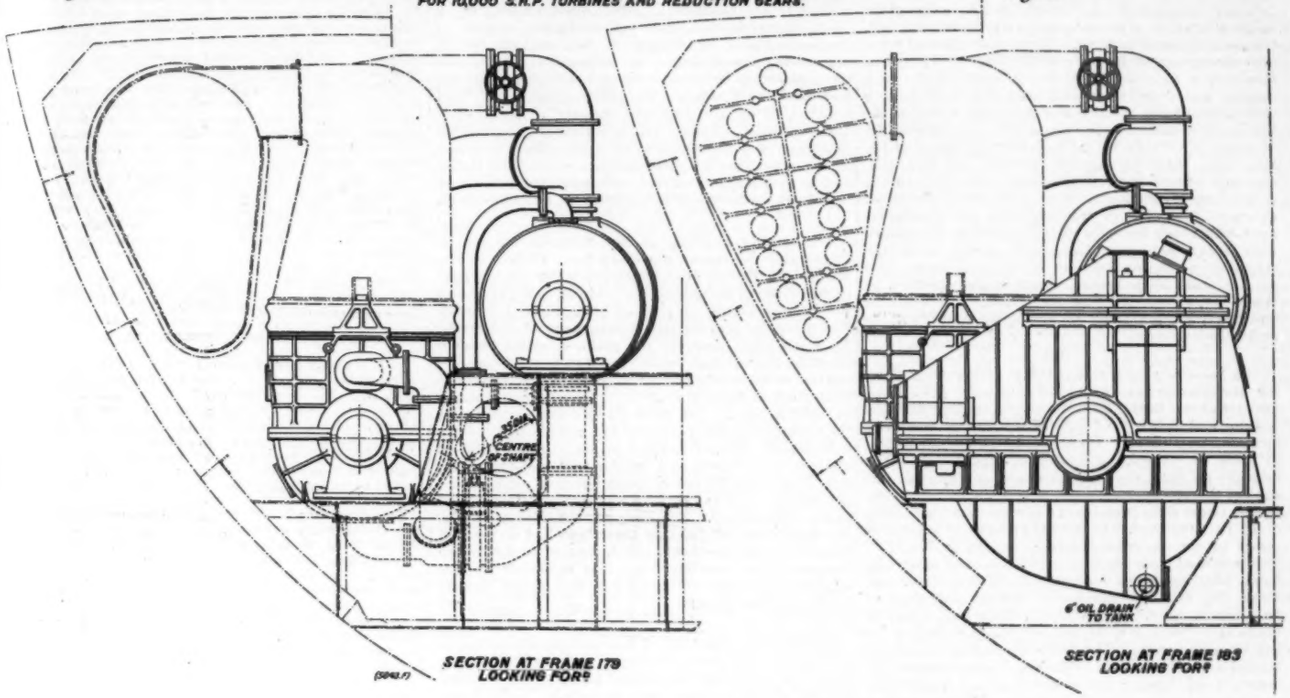


Fig. 10.


8" MAIN STEAM FROM BOILER.
H.P. TURBINE EXHAUST PIPE.
PEDESTALS ALIKE ON ALL TURBINES.
6 HOLES IN BEAM WHEN ERECTING.
6 HOLES IN BOILERS.
6 HOLES IN BOILERS.
72' 8"
6' 6"
THESE DIMENSIONS MEASURED ALONG SHAFT CENTER LINE.

REDUCTION GEAR OF FLOATING FRAME TYPE FOR THE S.S. "MAUI."

Fig. 11. ARRANGEMENT OF MACHINERY AND MAIN STEAM PIPES FOR 10,000 S.H.P. TURBINES AND REDUCTION GEARS. *Fig. 12.*



condensate removed by a turbine-driven centrifugal pump. The former weighs 108 lb., and the latter 740 lb. They replace an air pump of many times their weight.

The weight of the foregoing installation is 75 tons. This covers from the main turbine throttle and governor valve to the condenser inclusive; also the thrust block and reduction gears (but no shafting), circulating pump, with turbine and its gear, air ejector, condensate pump, auxiliary oil pump, gravity oil tank, oil piping, and cooler.

S.S. Maui.—This twin-screw ship is being built by the Union Iron Works, San Francisco, for the Matson Navigation Company. It will carry passengers and freight between San Francisco and the Hawaiian Islands.

Length over all	501 ft.
Breadth, moulded	58 ft.
Draught	29 ft. 11 in.
Displacement	17,500 tons
Full speed, loaded	17.5 knots
Full power	12,500 s.h.p.
Turbines, high-pressure and low-pressure	2,120 r.p.m.
Propellers	133 r.p.m.

Figs. 9 to 12, pages 322 and 323, show the arrangement of machinery for the port side. Fig. 11 is a sectional elevation showing the turbines and Fig. 12 one showing the gear. The turbines are cross-compound, reversible, and similar to those in the oil-tank steamer. To conform to the limitations of the engine room the high-pressure turbine actuates a pinion almost on top of the gear. Running either ahead or astern the high-pressure turbines may be used alone, exhausting direct to the condenser, and the astern turbines can transmit 60 per cent. of full ahead power.

The steam pressure at the high-pressure turbine inlet is 225 lb. per square inch with 50 deg. F. superheat. The contracted vacuum is 28.5 in. (30 in. barometer). Under these conditions the following performance is guaranteed:—

Total S.H.P.	R.P.M. Propellers.	Steam per S.H.P. Hour for Turbines.
10,000	125	11
8,500	120	10.7

There is only a single reduction from each turbine to the propeller, and the floating frame is of the same type as that shown in Fig. 2, Plate XXIX.

Maximum power per pinion ...	3,125 h.p.
Pitch diameter of pinion ...	7.794 in.
R.P.M. of pinion	2,120
Power constant	3.113

The lubricating system and auxiliaries are of the same type as those for the oil-tank steamer.

The weight of this installation, including the same parts as for the oil-tank steamer, except the condensers, oil pipes, and gravity oil tank, is 204 tons.

The introduction of the floating frame has been much accelerated during the last five or six months. There are in operation 102 gears, with a total of 126,442 h.p.; and on order 155 gears, with a total of 611,727 h.p. Besides the turbines and gears for land work and for the 45 freight ships and the Maui, the Westinghouse Machine Company are building the gears and, in all but two cases, the turbines for six warships, including a United States scout cruiser of 90,000 h.p. and a battleship for a foreign Government of 88,000 h.p. Indeed, principally to cope with this work the Westinghouse Electric Company, who have acquired the Westinghouse Machine Company, have begun to build, near Philadelphia, Pa., works which will be several times the size of their present extensive plant.

The simplicity of adjustment of the gear and pinion is remarkable. The pinion is placed in the floating frame and, by means of two gauges supplied with each gear, the distances of the centres of gear and pinion at the forward and aft ends of the floating frame are made equal; the holes for the bolts holding down the floating frame are then reamed. There is no scraping of bearings to bring the axes accurately into one plane and secure bearing all along the tooth face, as must be done with a rigid gear. The action of the teeth will do that, and, as the theory shows, however the bearings wear or alter under stress, good distribution of pressure along the teeth will be maintained. The gear is then run, usually under quite a light load, and the hard-bearing spots, if any, scraped. The work is then complete.

If the floating frame functions as stated, the wear on the teeth should be extremely small. A remarkable proof of this was given in the article of last year (referred to above) from the operation of the first floating frame gear installed, that at the Commonwealth Steel Company, Granite City, Illinois. This had not nearly so high a power constant as is now used, but it was reported that the maximum load reached 140 per cent. of its rating, under which condition the power constant is 1.68. It was started on March 31, 1911, and after running for 10 months night and day, five days per week, the load averaging 85 per cent. of its rating, the tool marks were still visible on the teeth. Mr. K. S. Howard, the chief engineer, has informed the author that this gear was last inspected on April 30, 1916, when they found the *scraper* marks still visible on the gear teeth. Originally these were of imperceptible depth. The driving face of the pinion teeth had taken on a very high polish and the gear was as quiet as at first. This is after more than five years of service. He further reports that since installation it has operated 24 hours per day, six days per week, with loads varying from 50 to 125 per cent. of rating, the average being close to full load, and he sees no reason why it should not operate satisfactorily for an indefinite period. There have been no repairs. The only discrepancy in the report is that, apparently, in the busier times of the last few years the gear has had to work under a greater average load and for one extra day in the week.

Again, there is a 1,000-kw. gear, guaranteed for 25 per cent. overload, at the San Diego Electric Railway Company's plant in California, which has been running 19 hours per day for five years. The superintendent of motive power states that it shows no sign of wear and that there has been no maintenance cost whatever. Similarly, two 5,500 h.p. single-pinion gears of the Cleveland Electric Illuminating Company have been in operation for four years, giving no trouble and without wear. These results are not exceptions, they are almost invariable, showing the great safety of the device in spite of frequent high-power constants. A further proof of the entire absence of point contact of the teeth is that chrome nickel steel has never been used for the pinions, as has frequently been done for rigid gears. Nickel steel has been used twice, to meet the physical characteristics required by the United States Government; but now these requirements have been changed and the pinions are always forged of a good quality of mild carbon steel.

PERSONAL.—M. B. Wild and Co., Limited, of Argyle-street, Nechells, Birmingham, have appointed as their sole selling agent for abroad, Henry Pynegar, 5, Dowgate-hill, Cannon-street, London, E.C. 4.

FLUORESCENCE AND PHOSPHORESCENCE.—Some practical aspects of the problems of fluorescence and phosphorescence were discussed in the March meeting of the Illuminating Engineering Society in connection with papers by Mr. F. Harrison Glew, Mr. J. S. Dow, and Mr. Arthur Blok. It is customary to speak of phosphorescence when the luminosity persists after the cessation of the stimulation by light and does not rapidly stop with it. But even the phosphorescence of zinc or calcium sulphide, luminous paint, &c., diminishes strongly in the course of a few hours. To prepare the paints the powdered sulphide is mixed with some varnish. The best results have so far been obtained, according to Mr. Glew, with mixtures of zinc sulphide and radium salts. But whilst the half-life period of radium is estimated at 1,000 years, these preparations drop by 50 per cent., and much more sometimes, in their luminosity within a year, especially when the radium percentage is relatively high, though the main luminosity is ascribed to the radium. This delay is probably due to some action of the radium on the zinc sulphide and also the varnish and the glass. A mixture containing 74 mg. of radium bromide per gramme of sulphide lost half of its luminosity—which was equivalent to the light of a glow-worm—in 24 hours. This mixture is extraordinarily rich. According to Mr. Dow, a 0.4 mg. mixture (0.4 mg. of radium salt per gramme of sulphide) would give about 0.4 foot-candle. Small phosphorescent patches are but little efficient; the luminous buttons, 1¼ in. in diameter, he found invisible at 10 ft. distance an hour after exposure, and they would not protect a man from being run over by a motor, therefore; in large patches strong phosphorescence might produce almost a glare, another reason for economising in radium. The advisability of coating lamp-posts, kerbstones, &c., with luminous paints seems doubtful. Mr. Blok discussed the methods of the National Physical Laboratory, of N. E. Dorsey, and of Clinton and Dow for the photometry of luminous substances; the first two of these we have noticed on other occasions.

INDUSTRIAL NOTES.

THE strike of engineers at Barrow—the occurrence of which was highly discreditable to the men involved, and a serious indictment against trade union control of industry—terminated on Thursday, when, acting on the result of a ballot of the men taken on Wednesday last, the men returned to work. There is no need to enter into the merits or demerits of the dispute. There is, however, a suspicion that the attitude of the men showed that their case was weak. The main point is that although the promise was made, on behalf of the Government and everyone responsible for the conduct of industry, to consider immediately the claims of the men upon their resumption of work, the men consistently refused until Wednesday to go back to the production of munitions vital to the prosecution of the war. The men return now upon the conditions upon which they left, and the employers, in accordance with recognised procedure, will confer with the constitutional representatives of the workpeople, and not with the Ministry of Labour or the Ministry of Munitions, on questions between them. There will be no delay, as the work of arranging terms will be undertaken at once.

The Secretary of the War Office makes the following announcement:—*List of Employees. D.R.* 17.—Defence of the Realm Regulation 41A, dealing with the posting and delivery of lists of employees, has been amended by Order in Council of March 13 and is now in force as revised. *Alteration of Age Limits.*—The exemptions from the regulation are not altered, but subject thereto the regulation now applies to everyone who in Great Britain employs one or more male persons of 16 years or over. Every such employer must now insert in the prescribed form: (*a*) Table No. I.—Particulars of male employees of 16 years or more who have been employed for more than one week. (*b*) Table No. II.—The number of female employees of 16 years or more. (*c*) Table No. III.—Particulars of males of 16 years or more who have been employed for less than one week. The respective tables have been altered accordingly, and table No. I now requires the insertion of further information as to employees' previous occupation, degree of skill, and work on which usually employed. The form (D.R. 17) containing the tables, with instructions for filling up the forms, has been revised, and copies are now obtainable from any post office, and should be used in complying with the regulation. A further amendment provides that employers shall, on being required by the Director-General of National Service (either by general or special notice) furnish a true copy of any of the statements as revised for the time being. This requirement is in addition to the existing obligation to furnish a copy, and the monthly statement of alterations and additions, to recruiting officers.

The impressions of the eleven American business men who visited France during September and October of last year in order to study and report on industrial conditions are given in *The American Machinist*. There was much to admire, the American delegates say, in the steel plants at St. Chamond, in the Berliet and Renault automobile factories, and in the steel and gun plant at Creusot. The general impression was formed that modern machine tools and labour-saving devices are not used in France to the same extent as in America, in plants of corresponding importance. The demand which the French factories supply is comparatively small, and it is therefore necessary for them to manufacture a wide range of products, instead of concentrating upon a limited standard output. The report adds that the French delight in good workmanship, and its prevalence is one of the many evidences of the artistic genius of the people. In some cases the finish appeared to the American delegates too careful and elaborate for the use to be served. For example, the highest degree of care may well be applied to an aeroplane, and those which the American delegates examined were models in this respect. The same is true, the delegates find, of the rifling and breech mechanism of field artillery, but in some cases unnecessary time appeared to be taken in finishing unimportant parts of a motor truck or a gun-carriage. We do not agree with the American delegates' report in regard to the latter, for we believe there is not one single unimportant part in a gun-carriage.

A plan to promote the welfare of the engineering profession, says *The Iron Age*, New York, has just been completed by a sub-committee of the National Committee on Engineering Co-operation; the report of the sub-committee was to be considered at a meeting to be held in Chicago. The plan to be discussed included methods of strengthening and unifying the work of the national engineering societies in the advancement of engineering knowledge and practice, and the maintenance of high professional standards; the invigorating of local societies adapted to local needs and exemplifying in their activities the principle of complete home rule; encouraging the adoption of enforcement by local engineering societies of codes of ethics in harmony with the standards used by the national organisations; the development of a scientifically-planned and well-conducted system of employment, to be worked in co-operation by all engineering associations; the diffusion of information on engineering subjects or proper advertising of the profession as a whole; the encouragement of local societies to devote time and thought to local, state and national affairs which influence engineering progress; the maintenance of a travelling secretary of the committee on co-operation to visit local bodies and to give personal advice and assistance in securing the highest efficiency and economy in administration.

The annual meeting of the National Society of Dyers and Colourists was held last Friday at the Manchester School of Technology, when Dr. A. Rée, in the course of his presidential address, called attention to the increasingly important part which chemistry was going to play in the development of industries. He stated that many of the main, so-called German chemical inventions were not made in Germany at all; on the other hand, a large number of the successful German inventors had spent years of their training in Great Britain. The speaker added that shortly after the outbreak of war Germany had completed her large installations for the production on a grand scale of nitrates from the air, and but for that fact she would have had to sue for peace within less than a year, since her supply of Chile saltpetre was by that time cut off pretty completely. Speaking of the Patent Laws, Mr. Rée further stated that these laws had in the past been of serious detriment to the success of the British aniline colour industry. He laid emphasis on the extreme importance of having foreign-owned patents worked in this country.

Addressing a meeting of his constituents in Leeds last Sunday, Mr. James O'Grady, M.P., said he had no objection to Labour Exchanges as such, but his contention was that a new national activity could not be handled effectively and thoroughly by machinery which was established for dealing with pre-war labour questions.

JOHN WRIGHT AND EAGLE RANGE, LIMITED, BIRMINGHAM AND LONDON.—Mr. H. James Yates, chairman and managing director of this company, presiding at its annual meeting, held in Birmingham on March 14, said that one very important fresh development in connection with their furnace business was being completed. By the new arrangement he referred to the very large business of the Morgan Crucible Company, Limited, Battersea, in furnaces, would be taken over by the speaker's company, who would become the sole manufacturers of all furnaces sold by the Morgan Company. The patents of the two companies would be combined in all crucible furnaces, these being named in future the "Wright-Morgan furnaces."

THE SOCIETY OF ENGINEERS (INCORPORATED).—A paper on "Ball Bearings" was read on Monday, April 2, 1917, by Mr. A. Marshall Arter, F.S.E., A.M.Inst.C.E., M.Inst.A.E., in the apartments of the Geological Society, Burlington House, Piccadilly, London, W. A brief *résumé* was given of Professor Stribeck's investigations. Before these investigations were made little was known beyond Henry Hertz's theoretical deductions on the contact of elastic bodies. Professor Stribeck measured the approach of hardened steel balls under compression, and found that the admissible static loads varied as the square of the diameter; he also found that ball bearings in which the load is carried at right angles to the axis of rotation of the balls were alone suitable for heavy loads. It was pointed out that the balls in modern ball bearings did not burst, but that the surface flaked out when overloaded, the load-carrying capacity depending upon the elastic limit of the surface of the steel. The author pointed out that the ball bearing of to-day could never have been made a commercial success but for the very high degree of accuracy in its manufacture. If a load of 130 lb. is put upon a ball $\frac{1}{4}$ in. in diameter, it is compressed $\frac{1}{1000}$ in., and hence if one of the balls in a thrust bearing is $\frac{1}{1002}$ in. larger than the rest, or there is a high place in the race of this amount, failure is certain if the normal load of the ball is at all approaching the safe working limit. The relation of load to speed was dealt with, and it was shown that the safe working load of a ball was reduced on increasing its speed of rotation, in thrust bearings the amount being greater than in radial ones. Professor Goodman's method of examining balls under a microscope for detecting overloading was explained. The gyroscopic effects, at high speeds, in thrust bearings, was next dealt with; it was shown that there is a certain minimum load necessary to prevent the balls skidding, due to gyroscopic torque, and that there is an absolute limit of speed at which a thrust bearing can be run, namely, when the maximum and minimum loads coincide. The author concluded with some interesting explanations of nomograms, their construction and use.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, Pa., March 13.

THE American Government orders for war material are overwhelming in quantity. The United States Steel Corporation has to-day orders for 11,576,697 tons. The Carnegie Company has booked an order for 350,000 tons of war material, and this is only the beginning. The Bethlehem Company has taken an order for 65,000 tons of plate for Cunard ships, which is the beginning of a number of other orders. Demand for ship-plate overcrowds all others. Large orders are being turned away. The shipyards are working to capacity. British interests want 18,000 tons of plate for six tank ships. Spanish yards, 6,000 tons of plate. Inquiries at home cover 60,000 tons. Equipment manufacturers are deluged with orders. Capacity was reached several weeks ago. The Standard Steel Car Company, at its works in France, will build 10,000 small freight cars. Spain wants 2,000 cars. The Lehigh Valley wants 56 Baldwins. The Chicago and North-Western wants 120 locomotives. There is whirl and excitement everywhere for material. The above-mentioned orders indicate only in a brief way the conditions in the United States. How we will pull out no one may foretell. The impending precipitancy of war with Germany is only troubling, but there is determination.

THE SUPPLY OF LOCOMOTIVES.—If the American railroads had 15 per cent. more motive power than they have, says *The Iron Age*, the traffic situation would be a great deal better. Shippers have all observed that the difficulty of the situation is not that cars are lacking, but that the cars do not move. Cars that are stationary block the movement of other cars, and shippers find there is as much difficulty in moving cars after they are loaded as in furnishing them for loading.

THE UTILISATION OF HYDRAULIC POWER IN INDIA.—The Government of Bombay have given permission to Messrs. Tata, Sons and Co., Bombay, to survey the Koyna River Valley between Mahableshwar and Helvek with a view to developing its probably immense hydraulic power resources in the manufacture of such products as aluminium, nitrates and artificial fertilisers. The investigation work is being pushed forward by their engineering department with the hope of outlining a practicable project. There appears to be a good natural harbour site within reasonable distance.

HEATING RIVETS.—A test recently made by the Newport News Shipbuilding and Dry Dock Company to check the cost of operating a rivet-heating furnace by gas, as against the oil furnace formerly employed, showed that more time was required by the gas furnace and the fuel cost was also increased, says *The Iron Age*. The results, it is understood, showed that 400 lb. of rivets were heated in the oil furnace in 44 minutes at a cost of 52.5 cents, assuming that the oil cost 6 cents per gallon; while the cost of heating a similar quantity of rivets in a gas furnace, with gas at 55 cents, was 53.6 cents, and the time required was 57 minutes. It is stated, however, that the rivets heated in the gas furnace were better than those heated in the oil furnace, as there was practically no scale upon them, while those heated by oil were badly scaled in a number of cases. The gas-heated rivets are said to stay hot enough to drive longer than those heated in an oil-fired furnace because the former are thought to be heated evenly all the way through, while the oil-heated rivets are extremely hot on the outside but are not hot in the centre, and thus cool more quickly.

ELECTRIC LOCOMOTIVES FOR CHILI.—The General Electric Company, of Schenectady, recently shipped three 120-ton electric locomotives to the Bethlehem-Chile Iron Mines Company at Tofo, Chile. The parts of a single locomotive occupied eight freight cars, and although one package alone weighed 23 tons the shipments were put aboard vessels without mishap and made the 40-day voyage to Cruz Grande. Each complete locomotive is equipped with four G.E.-253, 1,500-volt to 3,000-volt motors, having a normal one-hour rating of 240 h.p. each on 2,400 volts. The locomotives are geared for a speed at a rated load of 12.2 m.p.h., and are capable of exerting a tractive effort of 42,000 lb. at the hourly rating. Each locomotive is equipped with Sprague General Electric type "M" multiple-unit control and regenerative electric-braking apparatus. The railway is 15 miles in length, extending from the port of Cruz Grande (about 300 miles north of Valparaiso, Chile) to the mining village, located about 4 miles inland at Tofo. The iron mine at this point is located about 2,200 ft. above sea-level, and consists of two hills of iron ore, which is removed somewhat after the manner of trap-rock quarrying. There is a uniform grade of 3 per cent. for 14 miles, and for about one mile near the mines of 1 per cent. The trains will consist of an electric locomotive and from twelve to twenty 50-ton ore cars. On account of the elevation of the line all the loaded cars come down grade. The regenerative braking control will permit the locomotives to descend the grades with ordinary loads without the use of air brakes, thus returning power to the system and also making an appreciable saving in wear on brake-shoes, wheels and rails. The air-brake equipment will enable the locomotive to descend with a greater load than can be held back by the regenerative braking equipment alone. The cars are provided with an empty and loaded brake, to secure the maximum braking power on each car, whether empty or loaded. The trains will descend at about 12 miles an hour, at which speed, with a trailing load of 1,500 tons, the locomotive will return approximately 1,000 kw. to the line.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The constantly increasing demand of the Government for all classes of steel required for war purposes is placing a particularly heavy strain on manufacturers, who, while earnestly desiring to do all in their power to keep level with this demand, have had to face many serious labour problems—the shortage of skilled workers the most important. A feeling is now being entertained that the National Service scheme may relieve them of some of their difficulties, and that in consequence of this general dilution of labour more assistance may be available. Other than this, no very noticeable feature has occurred during the past week, except the efforts further to speed-up the output of steel both for the War Office and the Admiralty. The steel required for the standard boats is now a very heavy item also, but active steps are being taken to render it possible for producers to supply, by the scheduled time, the necessary material. Export rates, while firm, are practically without change, and steel ship plates continue to be quoted at or about 14*l.* 5*s.* per ton; boiler plates, 15*l.* 5*s.* and up; and angles, 14*l.* 2*s.* 6*d.*, or thereabouts.

Malleable Iron Trade.—Even with every available mill running to its fullest capacity, and the entire production devoted exclusively to war material, malleable iron makers report extreme pressure, alike in the iron and steel departments. While a limited quantity of the iron is available for export, the Government restrictions on the shipment of steel products prevent any of the steel finding its way overseas. To a certain extent this is prejudicial to the future interests of the makers, who, meantime, are unable to consider any business offered them by those who were their best customers in pre-war days. The price for "Crown" bars remains firm at 15*l.* per ton, but a higher rate is readily paid when prompt delivery is an urgent necessity.

Scotch Pig-Iron Trade.—During the week the position of the pig-iron trade has shown little or no change—there is still the same extensive demand for all grades, particularly for hematite, and the same feverish anxiety to get the material as quickly passed from producer to consumer as is at all possible. In some instances this has even had to be accomplished by means of artificial cooling. Foundry iron has been so much in request that no unsold parcels are now obtainable in the market. Prices are steady, and likely to remain so on account of the shortage of supplies.

THE PUBLIC SCHOOLS YEAR BOOK, 1917.—This year book for 1917, the twenty-eighth annual edition, is edited by Mr. H. F. W. Dean, M.A., F.S.A., and Mr. A. Bulkeley Evans, M.A., and is issued at the price of 6*s.* net by The Year Book Press, 31, Museum-street, London, W.C. It gives detailed information on the Public Schools throughout the country and useful information on the careers which are opened to students.

GERMAN PESSIMISM.—In spite of all protestations to the contrary, both in high quarters and low, many a far-seeing German, in diverse walks of life, views the future with serious apprehensions, and now and again statements to this effect are voiced, even in highly influential quarters. Such views were expressed at a recent meeting of the Union of German Merchants; from German shipping circles pleadings are also constantly being put forward for extensive State aid owing to the difficult and trying conditions which German shipowners will have to meet when their enforced and protracted inactivity comes to an end. The German Government will no doubt be willing to lend a helping hand, presumably in the shape of subventions or loans, free of interest, redeemable within a period of probably 20 years, and intended to forward as much as possible the building of new ships. This is all very well, as far as it goes, but in the opinion of German shipowners it does not go far enough. Vessels contracted for now will be handicapped by the extortionate prices ruling, and by the time such new vessels are ready, in all probability not before 1920–22, freights will most likely have found their proper and natural level, at which tonnage built at a very high cost will be unable to pay its way, even reckoning with the facilities likely to be granted by the Government. There is, further, the question of compensation for vessels lost during the war or captured by the enemy, a matter which will necessitate heavy writings-off, and with regard to which uncertainty still prevails in Germany. German shipping, since the war broke out, has, moreover, had to meet, and is still compelled to meet, a number of heavy expenses, for maintenance, harbour dues in neutral ports for interned vessels, wages, &c., which all drain the reserve funds to an alarming extent; and during all this time of trial for the German merchant navy this latter sees neutral and hostile shipowners "reaping a golden harvest," paying unprecedented dividends, and consolidating their concerns in a manner which will benefit them both for the near and more distant future.—The directors of the Vulcan Shipbuilding Yards, of Hamburg and Stettin, have published a statement about the prospects of German shipbuilding in the years after the war. They say that they are inclined to a policy of caution, because, although they are sure that Germany will "recover her former position and more in world trade," the length of the war has created very many problems which will be difficult to solve. They say that the existing German yards are quite sufficient to produce the necessary tonnage in the period of three or five years after the conclusion of peace, and they consider that there will be a scarcity of labour.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—The unexpected has again happened, and upset calculations. Dealers and depots had anticipated that the spring would bring a spell of warmer weather to relieve the congestion of orders, but the snowstorm has added to their difficulties to a marked extent. Orders for all classes of fuel have poured in, and increased the arrears already on the books. The house coal section is particularly busy at a time when it is customary to look for some pronounced falling-off in trade following the advent of more congenial weather. Manufacturing sorts are also wanted in bigger numbers, and gas companies have asked to be supplied with augmented deliveries. The circumstances combine to render the position one of great difficulty. Collieries are handicapped through transport troubles, and also with the traffic delays consequent upon the fall of snow. It is not expected that the Easter holiday interval will make any appreciable difference, for works are eager to obtain all supplies, in the hope of being able to build up substantial reserve stocks. The pits are likely to stand idle for two days. Exports are not on a large scale, except the trade done with allied Powers, and in those cases the figures do not come under the ordinary export classification. Sales to neutrals are about 8*s.* per ton higher than those obtaining in home market transactions. Quotations:—Best branch handpicked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house coal, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; and smalls, 7*s.* 6*d.* to 8*s.* 6*d.* per ton at the pit.

Iron and Steel.—It is not considered advisable to have a uniform general holiday in the whole of the large works, but arrangements have been come to whereby the various individual firms are settling the dates for themselves, suiting, as far as possible, the claims of urgent work already in hand with the general convenience of their employees. In certain cases the works will close down on Friday night until the following Wednesday morning, but other works are only taking holidays on Friday and Monday. The approach of the holidays has not been reflected by any easier tendency in the material marked, as was usually the case before the war. Production, however, is now on so vast a scale that the demand for raw and semi-finished material seems almost insatiable. The military and naval authorities are wanting greater deliveries of all classes of work of national importance, whilst there has been much speeding-up locally in order that the Easter cessation may be enjoyed with as little interference as possible with the output of vital material. It is, however, necessary, both in the interests of men and machinery, that there should be some slight respite. Works managements complain that the policy of weeding out unskilled labour has been a trifle too thorough for their liking and the smooth working of their concerns. It is not placing it too highly to say that they look with scant favour upon the suggestions that their losses in this way will be made good through the operation of the National Service Scheme. Carting, and transport work present many difficulties. The Erith Corporation is the latest customer for tramway tyres, and has placed a substantial order. Saw makers have received further large indents, whilst the file trade has an extraordinary demand to meet. Sheffield agricultural engineers report that they are making good headway with their difficult task of meeting an unusually exacting demand with depleted staffs. All manner of farm and garden tools, beater plates, and the more intricate machinery have been manufactured on a satisfactorily large scale. There is stated to be a shortage of rake steel, but this can be remedied in time for the harvest season. Sheffield Chamber of Commerce, at its meeting on Monday, decided to protest against the action of the Government in cutting-off the supplies of cupro-nickel scrap from the plate trade. It is considered that unless something is done very speedily in the matter of conserving for this trade a source of raw material it will be dealt a death-blow—wittingly or unwittingly it matters not. Cutlery houses have plenty of orders on hand for home and export trade if they could be assured of the necessary quantities of base material. The general prosperity of the overseas trade is indicated by the arrival of an abundance of indents from all parts for sheep shears, bolts, castings, steel, files, saws, tools, knives, electro-plate, wire rope, and hardware.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—After having been stationary since July last the official maximum quotations of Cleveland pig-iron for home consumption have this week been advanced by 5*s.* per ton. Though official intimation of the change had not been made at the time of writing, news of the alteration is authentic, and all new business is being transacted on the basis of the rise, which was by no means unexpected, as cost of production has been going up, and employees, whose earnings are regulated by the selling price of iron, have been emphatic in their resentment of the effect of the fixed maximum in restricting advance in wages. The upward movement has not yet carried with it export quotations, but dealers with the Continent intimate that a rise is bound to be made. Market rates for home consumption now stand at 92*s.* 6*d.* for No. 3, No. 4 foundry and No. 4 forge, and 96*s.* 6*d.* for No. 1; whilst for shipment to our Allies they remain at 97*s.* 6*d.* and upward for No. 3, No. 4 foundry, and No. 4 forge, and 102*s.* 6*d.* and upward for No. 1.

Stock of Cleveland Pig-Iron.—During the month of March there was only one change in the stock of Cleveland pig-iron in the public warrant stores, a withdrawal of 146 tons of No. 3 on the 27th. The quantity held now stands at 2,147 tons, composed of 2,111 tons of No. 3 quality and 36 tons of other kinds of iron deliverable as standard. There are warrants in circulation for 1,750 tons, all No. 3 quality.

Hematite Iron.—Sellers of East Coast hematite iron declare that the situation justifies a substantial rise in prices, but as yet there is no news of any advance. All legitimate home needs are being satisfactorily met, and export trade is being dealt with as expeditiously as circumstances permit, but the tonnage question still hampers despatch. Nos. 1, 2 and 3 are nominally 122*s.* 6*d.* for home use, 137*s.* 6*d.* for shipment to France, and 142*s.* 6*d.* for export to Italy, but sellers are very disinclined to entertain offers on these terms.

Manufactured Iron and Steel.—There is little new to report concerning the finished iron and steel industries. Manufacturers continue working at heavy pressure and are still steadily adding to their very heavy production. The output of mercantile shipbuilding material is reported to have assumed large proportions and to be still growing to a gratifying extent, notwithstanding pressure for delivery of other descriptions. Prices are strong. The following are among the principal quotations to home customers:—Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship-plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 17*l.* 10*s.* to 18*l.* 10*s.*; packing iron and steel (parallel), 13*l.*; packing iron and steel (tapered), 15*l.* 5*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship-plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 19*l.* to 20*l.*; steel boiler plates, 12*l.* 10*s.*; steel strip, 17*l.*; steel hoops, 17*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*

Shipments of Iron and Steel.—Shipments of iron and steel from the Tees for March amounted to 87,260 tons, of which 53,545 tons were pig-iron, 2,396 tons manufactured iron and 31,319 tons steel. The loadings of pig for the previous month reached 62,010 tons, and the shipments of pig for March last year were returned at 40,886 tons. Of the pig-iron cleared during the third month of this year 51,923 tons went to foreign countries, and 1,622 tons to coastwise customers; whilst all the manufactured iron and steel shipped went abroad. Again, France was much the heaviest customer, receiving 71,266 tons, composed of 41,268 tons of pig-iron, 1,119 tons of manufactured iron and 28,879 tons steel, Italy being second with 7,761 tons, 6,900 tons being pig-iron, and 861 tons steel; and the United States third with 2,800 tons of pig-iron. India imported 1,773 tons of which 200 tons were pig-iron, 904 tons manufactured iron and 669 tons steel.

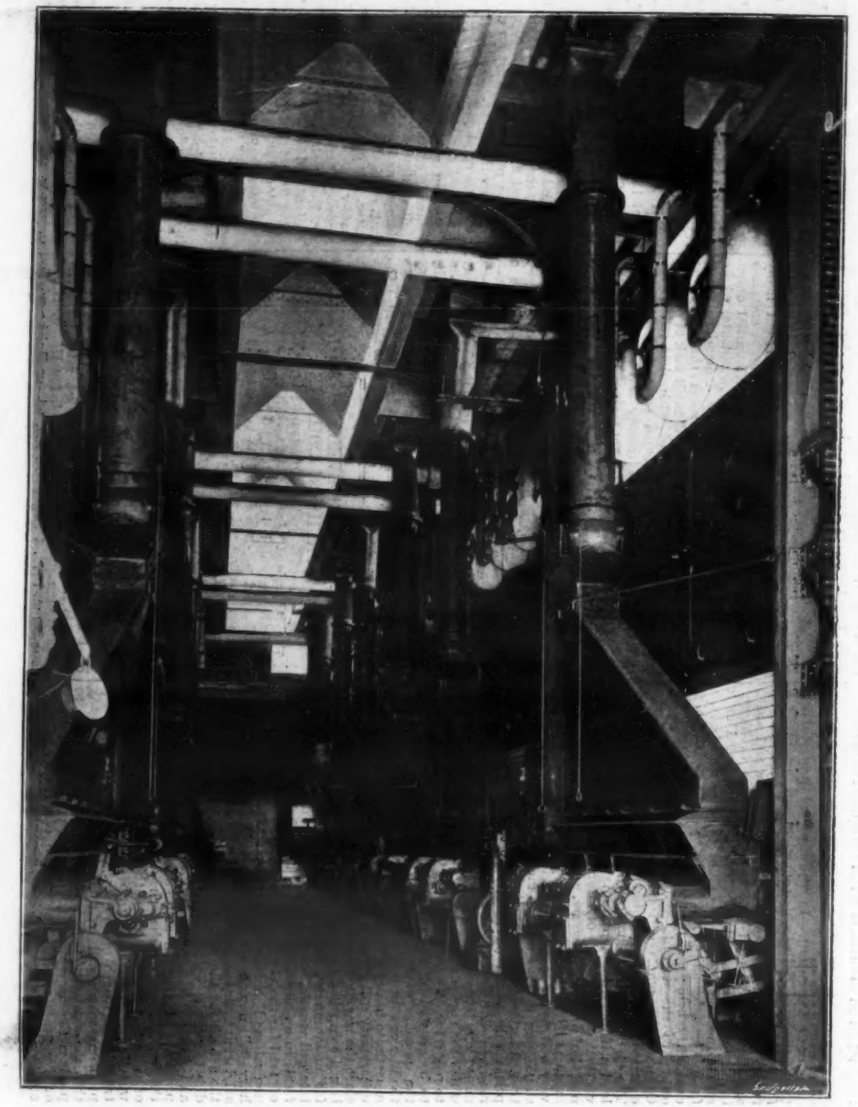
GERMAN WAR PROFITS.—The Rheinische Metallwaren- und Maschinenfabrik, Derendorf, near Düsseldorf, has earned gross profits of 21,417,858 marks for the financial year ended September 30, 1916, against 16,057,481 marks for the preceding year. After deducting 7,212,680 marks for various purposes, there remains, including a balance carried forward and interest surplus, an available sum of 15,303,675 marks, against 9,876,619 marks for the previous year; a sum of 10,000,000 marks is reserved for new plant and for placing the company, later, on a peace basis. The preference shareholders obtain a dividend of 20 per cent. and the ordinary shareholders one of 18 per cent., against respectively 13 per cent. and 11 per cent. for the preceding year, in addition to a bonus of 100 marks per share, of both classes. A sum of 1,093,883 marks goes to the board, against 193,211 marks for the previous year. All branches were employed to their fullest capacity during the current year, and new buildings and plant had become necessary. During the year 1915–16 the number of hands employed averaged 24,614, who earned an average of 6.59 marks per man per shift against an average of 5.80 marks for the preceding year. At the present time over 34,000 hands are employed.

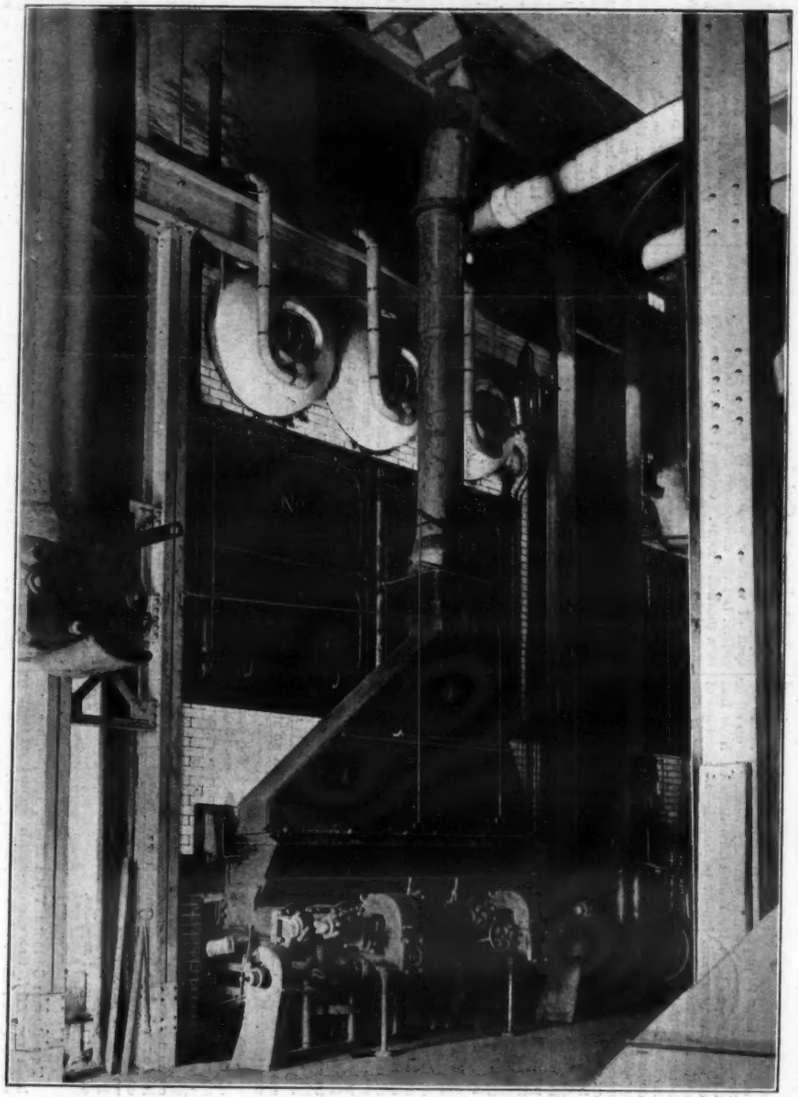
POTASH FROM WYOMINGITE.—Wyomingite is a lava occurring extensively in the Leucite Hills of Wyoming, United States. The mineral leucite is a silicate of alumina and potash, and far richer in potash (11 per cent. of K_2O) than is feldspar. Though not soluble in water, the potash in leucite was considered to be more readily attackable than in other minerals. The potash recovery from wyomingite has hence been investigated by Mr. Roger C. Wells (United States Geological Survey, Professional Paper 98–D). The wyomingite contains about 36 per cent. of leucite, but there is also potash in the phlogopite and in the silica base of this lava. Flotation of the crushed wyomingite proved only partly successful for the separation of the constituents. Cold water attacked leucite slightly. Heating the wyomingite alone had little effect. Heating the rock with gypsum and with sulphuric acid rendered about 25 per cent. of the potash soluble. Heating with alunite (practically an aluminium sulphate, occurring in the neighbourhood) gave better results; the potash of the alunite (10 per cent.) also became available. Experiments with potassium bisulphate and with calcium carbonate were unsatisfactory; heating with calcium chloride at temperatures not exceeding dull-red heat rendered up to 73 per cent. of the potash soluble; at high temperatures (1,000 deg. C.) an insoluble glass was formed. Some success was also realised with magnesium salts.

COAL-HANDLING PLANT AT NARRAGANSETT, PROVIDENCE, R.I., U.S.A.

CONSTRUCTED BY THE C. W. HUNT COMPANY, ENGINEERS, WEST NEW BRIGHTON, N.Y., U.S.A.

(*For Description, see Page* 318.)





THE STRENGTH AND INNER STRUCTURE OF MILD STEEL.

(*For Description, see Page* 319.)

Fig. 3. Magnified 40 Diameters.

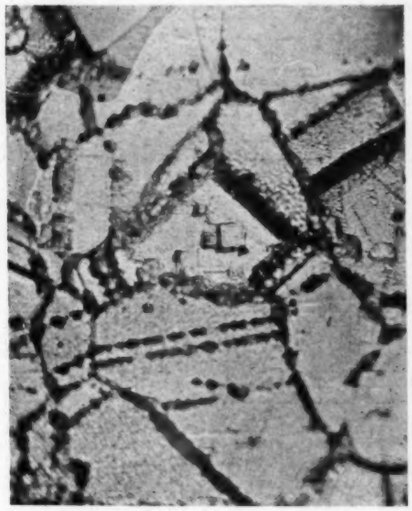


Fig. 4. Magnified 500 Diameters.

Fig. 5. Magnified 1000 Diameters.

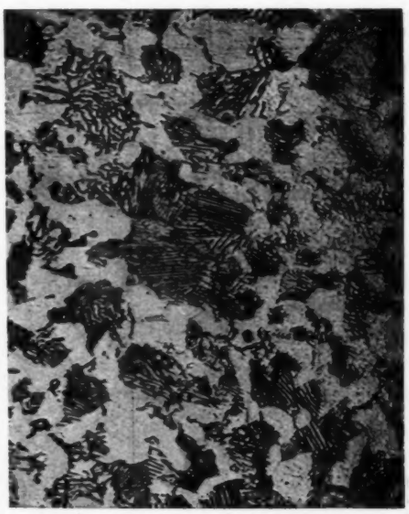


Fig. 6. Magnified 1000 Diameters.

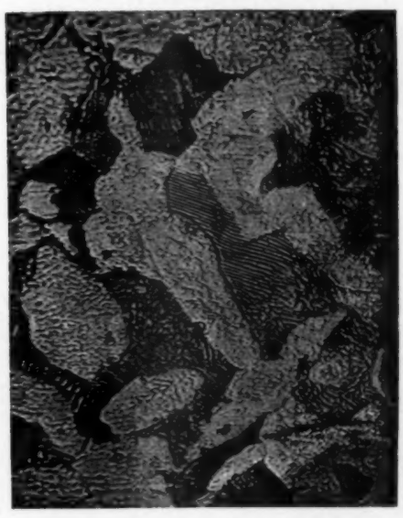


Fig. 7. Magnified 1000 Diameters.

Fig. 8. Magnified 500 Diameters.

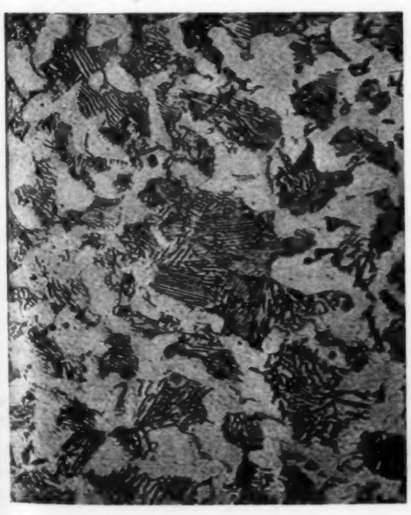


Fig. 12. Steel, 0.57 Carbon. Annealed. Magnified 1000 Diameters.

Fig. 13. Heated to 900 Deg. C. and Cooled Rapidly in Water. Magnified 1000 Diams.

Fig. 14. Heated to 900 Deg. C. and Cooled Slowly in Lime. Magnified 1000 Diams.

(*To face page* 318.)

MARINE APPLICATIONS OF REDUCTI G

(For Descrip ns Pa

Fig. 1.

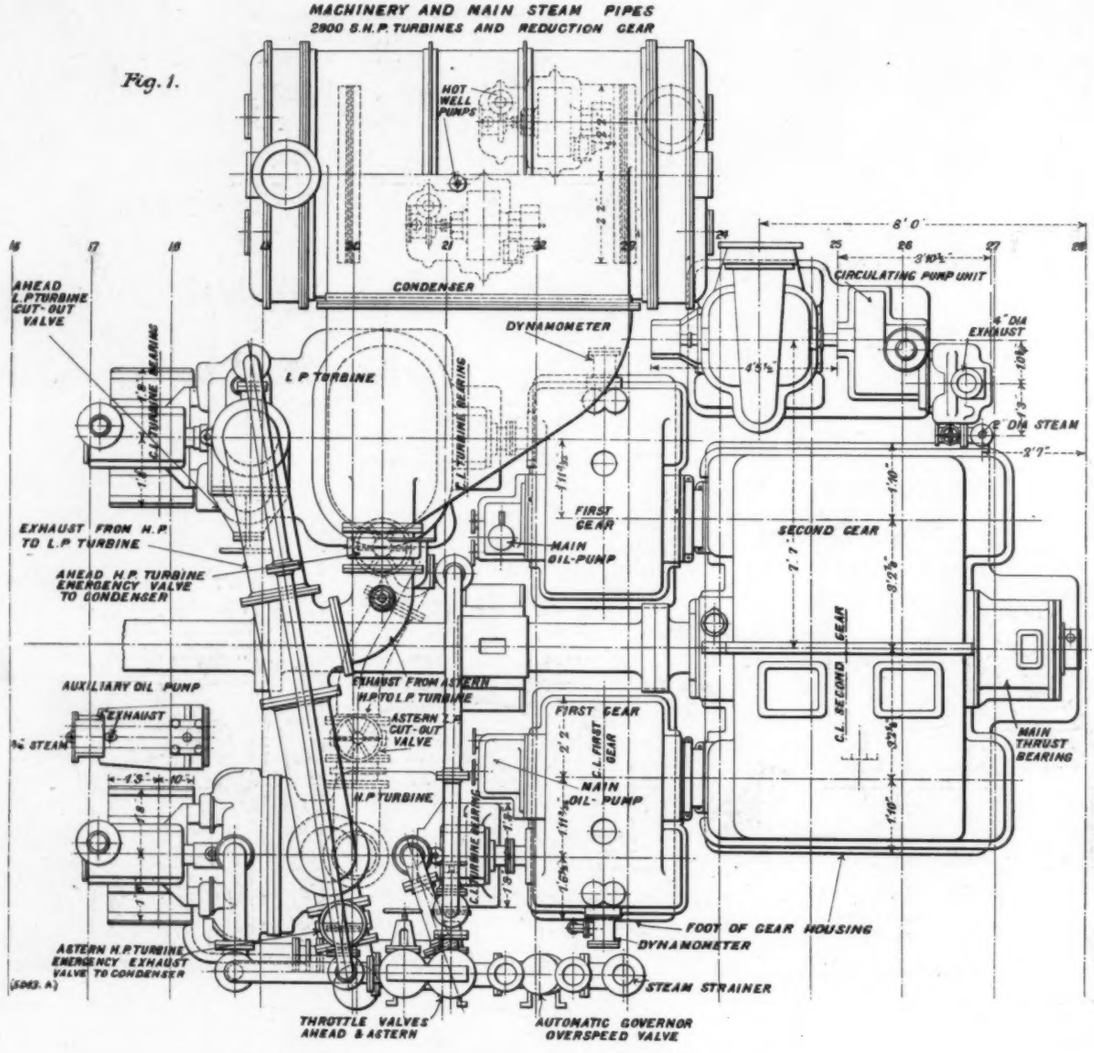
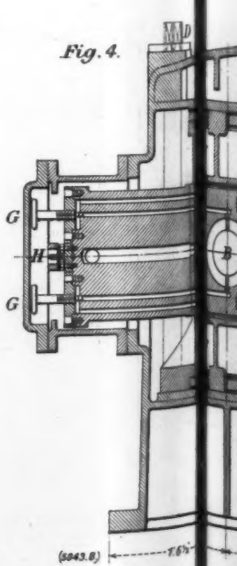


Fig. 5.

Fig. 2.

Fig. 3.

Fig. 4.



CTI GEARS OF FLOATING FRAME TYPE.

r Descrip on Page 321.)

UCTION GEARS 1450 S.H.P

Fig.2.

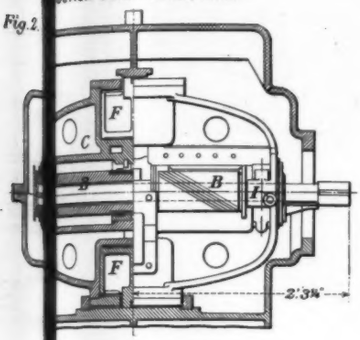
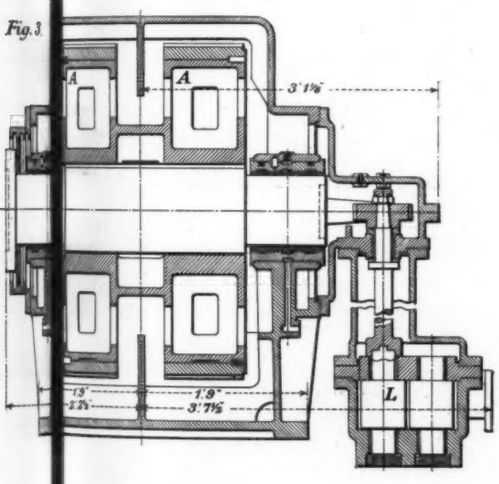
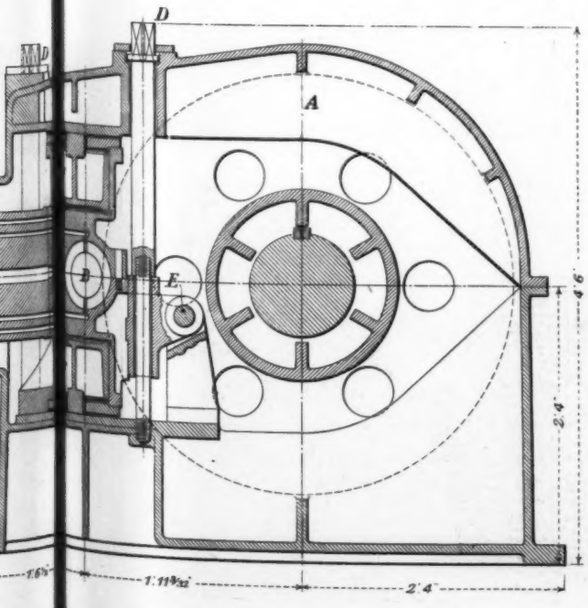


Fig.3.





REDUCTION GEARS. 2900 S.H.P.

Fig.6.

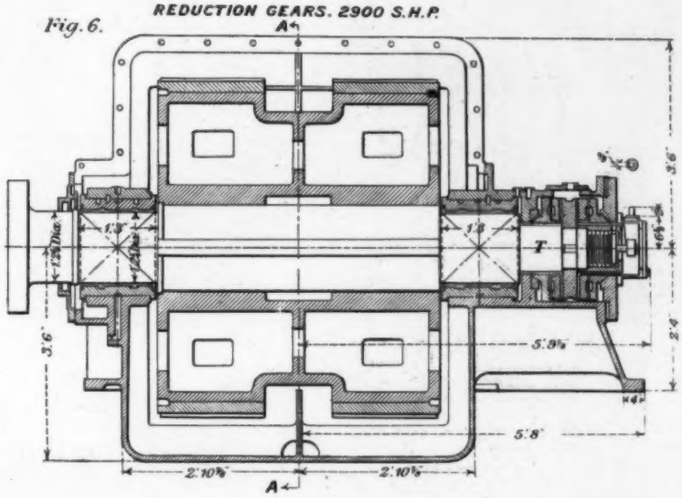
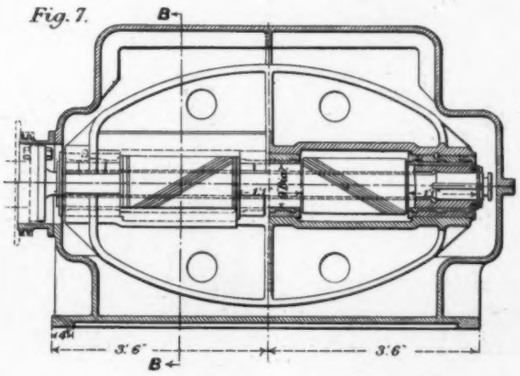
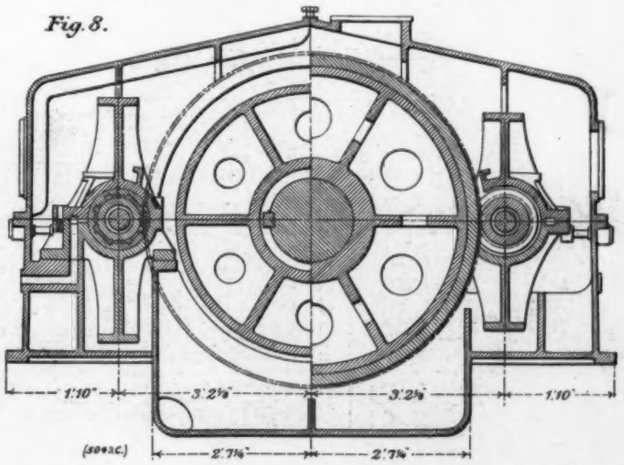


Fig.7.



HALF SECTION A.A. HALF SECTION B.B

Fig.8.



THE STRENGTH AND INNER STRUCTURE OF MILD STEEL.

(*For Description, see Page* 319.)

FIG. 17. MAGNIFIED 500 DIAMETERS.

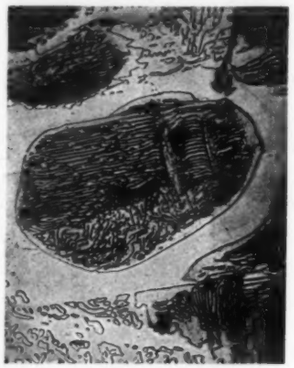


FIG. 18. MAGNIFIED 500 DIAMETERS.

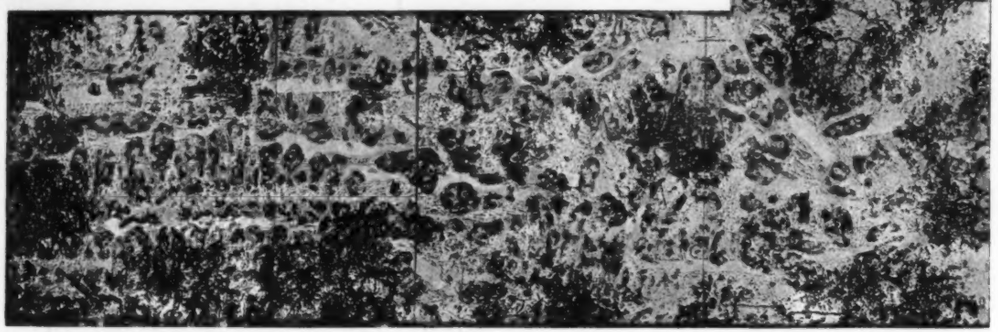
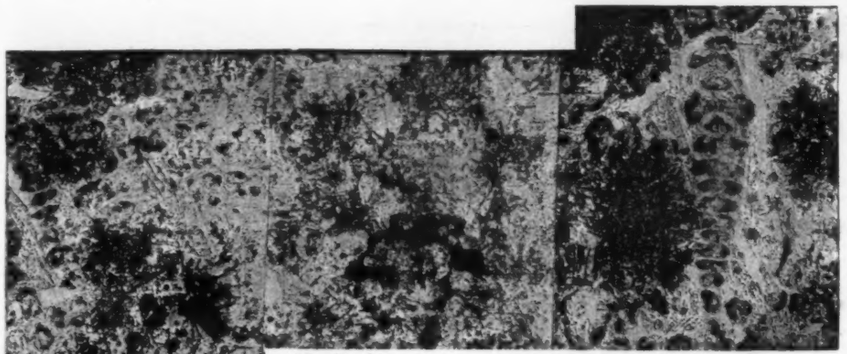


FIG. 15.



Magnification × 62

This shows the real area examined.

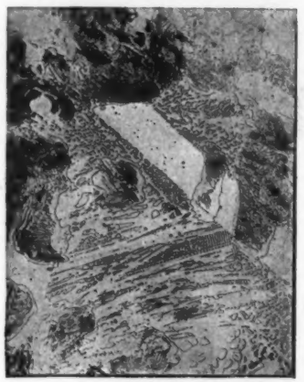


FIG. 16. MAGNIFIED 250 DIAMETERS.

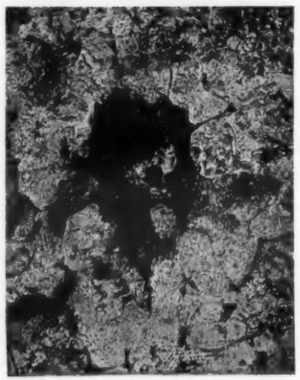


FIG. 19. MAGNIFIED 125 DIAMETERS.

FIG. 20. MAGNIFIED 500 DIAMETERS.

FIG. 21. MAGNIFIED 500 DIAMETERS.

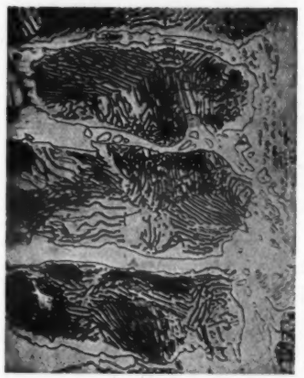


FIG. 22. MAGNIFIED 500 DIAMETERS.

FIGS. 17 TO 22. MOTTLED PIG IRON.

(*To face page* 319.)

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The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

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TELEPHONE NUMBERS—3063 and 8596 GERRARD.

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With One Two-Page Plate of MARINE APPLICATIONS OF REDUCTION GEARS OF FLOATING FRAME TYPE, and Two One-Page Plates of the STRENGTH AND INNER STRUCTURE OF MILD STEEL.

NOTICES OF MEETINGS.

THE MINING INSTITUTE OF SCOTLAND.—Saturday, April 7, at 3 p.m., in the Royal Technical College, George Street, Glasgow. The Council will submit their annual report. Address by the President. Mr. John B. Thomson's paper on "The Chalmers-Black Visual Indicator" will be discussed. Mr. Thomson will give a further demonstration with the indicator. Mr. David Ferguson's paper on "The Form and Structure of the Coalfields of Scotland" (read at the annual meeting of the Institution of Mining Engineers, held at Glasgow on September 14, 1916, see Part 3, vol. lii of the Transactions) will be open for discussion.

THE INSTITUTE OF MARINE ENGINEERS.—Tuesday, April 10, at 7 p.m. Subject:—"Standardised Marine Engines," by Mr. W. Veysey Lang, Member.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, April 11, at 8 p.m., at the Royal Society of Arts, John Street, Adelphi, W.C., when Lieut.-Colonel R. E. Bagnall-Wild will read a paper entitled "The Use and Abuse of Steel in Aircraft Construction."

THE INSTITUTION OF RAILWAY SIGNAL ENGINEERS.—Wednesday, April 11, at 2.30 p.m., at the Midland Grand Hotel St. Pancras, when a paper on "Automatic Signalling" by Mr. C. H. Ellison, will be discussed.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, April 12, at 6 p.m., at the Institution of Civil Engineers, Great George Street, Westminster, S.W. "Wayleaves," by Mr. C. Vernier, Member.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal from 6d. to 8d. per copy. This increase dated from and included the issue of Friday, March 16. The change will not apply to unexpired subscriptions.

ENGINEERING.

FRIDAY, APRIL 6, 1917.

THE EDUCATION OF APPRENTICES WITHIN WORKS.

IT was inevitable that the final report of the Departmental Committee, presided over by Mr. Herbert Lewis, on juvenile education in relation to employment, issued this week, should devote most attention to reforms in the work in the elementary school. This is all-important, as it is concerned with the foundations upon which the life-work of all must be built. Employers are not concerned with this; but their duties and responsibilities will not thereby be lessened. Thus in view of the many changes in the relationship at present existing between employers and employed, which are not only advisable but essential in the interests of both parties and of the trade of the country in the industrial struggle which will follow the cessation of hostilities, it is perhaps pertinent to inquire whether employers as a whole have grasped the significance of their own responsibilities in the matter of the provision of the necessary facilities for the technical and trade education of those workers on whom the hope for the future is founded. It would be well to consider briefly what are the facilities at present available, how far these fulfil the purpose for which they exist, and how far they conform to the ideal of increased efficiency which must be the aim of all future industrial effort. So far as the average apprentice in the shipbuilding and engineering trades is concerned instruction within the works in the meaning and details of his trade simply does not exist. There are in most busy centres excellent technical evening classes at which the willing apprentice may learn something of the theory of shipbuilding, engineering or the allied trades, but the proportion of apprentices who, on starting their trade, have a sufficiently high standard of education to benefit by the instruction given in the technical classes is woefully small—possibly 10 per cent. is over rather than under the figure. To meet the case of the more backward majority evening continuation classes are held, and these aim at carrying on and extending the work of the day school to the point where the pupil may profitably enter the technical classes. For many reasons these classes are not extensively taken advantage of, and the education of the apprentice thus remains on the level which it had attained on his leaving school.

As it is obvious that a continued attendance at classes of some sort must be a preliminary to any extension of education, it is of interest to examine the reasons for the comparative failure of the continuation classes, and in that way to seek a remedy. The main causes are found on investigation to rest on a very human and intelligible basis, and are (1) the sense of manhood and independence which a boy acquires on his first becoming a wage earner and his consequent desire to escape from all suggestion of the petty tyrannies of school life; (2) his utter failure to see how the subjects taught at the continuation classes are going to help him in his particular trade; (3) a disinclination to put himself voluntarily under an irksome discipline for an additional two hours on perhaps three evenings a week after his long day at work; and (4) the unsettling effect due to the loss of a few nights at the class on account of late work. The first of these causes it is practically impossible to remedy by direct means, and a remedy is only to be found by a revision of day school methods and by fixing a standard of attainment for leaving school rather than a minimum age. The second objection is quite understandable, for it is certainly difficult for a boy starting to serve his apprenticeship as, say, a ship plater to understand how the study of English, algebra, &c., is going to benefit him, especially in view of the fact that his father—who is a journeyman plater—attended no classes. A little real interest by, and a few words of advice from, an intelligent foreman would in many cases do much to correct this point of view, while suitable recognition by the employer of diligence and perseverance would also do much to solve this difficulty. The third cause opens up a question of much greater difficulty than either of the others. Can the average boy of about 15 years be expected to reap any benefit from attendance at evening classes after spending the day from 5 a.m. till 6 p.m. at and travelling to and from his work? Is it reasonable to expect this of a young and growing lad in the early days of his apprenticeship and before he has become accustomed to the daily routine of work? It is easy to point to many cases of men in good positions who have come through this with the greatest credit, but these cases are exceptional and do not in any way affect the problem as it applies to the average boy. The fourth cause is all too well known to the class teachers, and is the cause of many promising boys being lost to the classes. The remedy for this lies entirely in the hands of employers, whose business it should be to ensure that no lad is compelled to work late on class nights. The efficiency of the present scheme of evening continuation-class education as it applies to young apprentices is therefore entirely dependent upon the ability of these lads to concentrate on class work after a long day in the yard or shops. That the existing facilities are by no means wholly satisfactory will be seen from what we have written, but they represent at least an honest effort toward the solution of the problem on the part of the educational authorities, and it is of interest to examine the attitude of employers in the matter.

Assuming that apprentices are willing and able to attend the classes and can accomplish satisfactory work under the present conditions, what definite inducement to perseverance is there for the lad whose only ambition is to become a skilled tradesman? In the vast majority of cases it must be confessed that there is none at all, for in most cases foremen neither know nor care whether their apprentices attend classes or not, or what progress they make if they do attend, and the individual work of the average apprentice in the yard or shop gives practically no scope for the exercise of originality or knowledge. That some encouragement was necessary was recognised by employers some years ago when certain firms announced that the fees paid by their apprentice pupils would be refunded to them on completion of a satisfactory session of class work. This was a step in the right direction, but inasmuch as the fees were generally paid by the parents, the direct advantage to the boys was not great. A much

(To face page 319.)

superior scheme, and one which deserves to be much more widely known and adopted, has recently been introduced by some of our more progressive firms. Under the new scheme all apprentices with one year of satisfactory work at their trade to their credit and who can furnish a certificate of satisfactory attendance and progress at the evening classes, and who, in addition, will undertake to attend the classes of the following session, are granted an increase of pay of 2*s.* per week for the ensuing year. This arrangement holds good for each year of apprenticeship, but the extra pay is at once discontinued in the event of failure to comply with the conditions as to attendance and progress at the classes. That this system of direct personal reward for increased personal effort will have the effect of increasing the attendance and intensifying the effort at the classes cannot be doubted. The fact that it is extended over the period of apprenticeship will also encourage the more advanced pupils to enrol in the science classes when they have attained to the required standard. That this scheme will result in a large increase in the numbers attending both the continuation and science classes is certain, and the result cannot fail to be of great benefit to the worker, the employer, and the country.

With regard to the "trade" education of the apprentice within the works the condition of things is in most cases deplorable in its utter lack of method or even of thought. As a rule no attempt whatever is made to teach the lad anything appertaining to his trade—he is simply put to a machine, shown certain mechanical operations and told to carry on, or he is put to work with a journeyman, for whom he fetches and carries and does odd jobs as required without any attempt being made to explain to him the nature and meaning of the operation or the reasons for the methods and tools employed. Information which the apprentice gains is as a general rule just what he can pick up for himself by keeping eyes and ears open, and this is, at best, a slow and not altogether reliable method. In this connection a drastic revision of methods is suggested by the fact that under stress of war conditions it has been found possible by means of a few weeks' tuition under an expert to employ women who had absolutely no knowledge of work or machinery on jobs which had in many cases previously been done by skilled men. It stands to reason that the same method could with profit be employed to a large extent in the training of apprentices in each branch of their trade. The benefits of some organised system of instruction in the various branches of the trade concerned would seem to be too obvious to require pointing out; it is only logical to assume that systematic instruction in the details of the trade which is to be his means of livelihood and which should be a source of profit to himself, his employer and the country is as necessary to the apprentice as is systematic and organised instruction in his class work. In view of the haphazard manner in which a trade is picked up during the five years of apprenticeship, can it be wondered at that the number of inefficient journeymen turned out each year is so large. Does this lack of systematic instruction not encourage the production of the very type of worker against whom so much is said and written at the present time? These two questions of the theoretical and practical education of the rising generation of workers are of first rank importance in their bearing upon the problem of the increased efficiency in production which all are agreed must be the aim of industry in the immediate future.

It is not our purpose in the present article to discuss in any detail what means should be taken to improve what must be admitted to be a wholly illogical position, but an indication of possible lines of progress may not be inopportune. In the first place the problem naturally resolves itself into the question of improved facilities for (*a*) present-day apprentices, (*b*) the apprentices of the near future. With regard to the present-day apprentices a difficulty at once arises due to the fact that a large proportion of lads have no ambition beyond the learning of just as much or as little of their trade as will enable them to earn a journeyman's wage. Admittedly this class is the most difficult to deal with, and it is from this class that the malcontents are very largely recruited in after-years. For these very reasons special efforts should be made to deal with them in such a way as to make it obvious that special skill will meet with its due reward. For such lads an excellent plan is the organisation of special classes held in the works at which a course of carefully prepared lectures would take the place of the evening continuation classes. These lectures would be arranged so as to cover the practical work of each group of trades concerned in, for instance, the building of a ship, or the construction of a set of engines or boilers and their auxiliary machinery. Calculations would be avoided wherever possible, and the maximum effort would be made to ensure that the subject-matter was such as could be understood by the lads. Extra wages on a scale slightly lower than for continuation classes would be allowed to diligent students whose work in the shops was satisfactory, and it should be made known that all appointments of leading hands, under-foremen, &c., would be made as far as possible from those who had done consistently good work in the classes and in the shops. This system has already been in operation not only for apprentices, but also for young journeymen in the shipbuilding trades, and the results have been most encouraging. The classes should be held under the direct supervision and control of the employers, and reports of progress made by the pupils should be furnished to the manager and head foremen concerned. For the more ambitious lads the present system of evening classes is excellent except in so far as the question of fatigue interferes with efficient study, and it then becomes a question of whether some arrangement can be come to whereby the time spent at classes can be arranged for during the day without interfering too seriously with the work of the yard or shop. Undoubtedly such an arrangement would be an immense advantage and is well worth striving for, but the difficulties are many and serious and must be left for future consideration.

The practical instruction in the works is a reform long overdue and could be taken in hand by the shop or outside foremen. Short informal talks about the work in hand, the methods employed and the tools used could be supplemented by walks round and explanations of the various jobs in hand, and would undoubtedly be of immense value to all concerned. The trade lectures referred to above would be of use here also, provided that they did not interfere with evening class work. It is, however, from an increased interest in the education of the potential apprentices of the near future that the desired results must be obtained in order to ensure the permanence and continuity of the development which is sought. For this reason it would be a very decided gain if it were made compulsory that all lads should remain at school until they had attained a standard which would enable them to attend technical classes without the necessity of attending continuation classes; no lad should be allowed to start work till he is 16 years of age unless the necessity of his contributing to the family support is proved. Starting at the age of 16 and with a good general education, the apprentice would be physically and mentally in a satisfactory state to attend the evening science classes with advantage; with suitable practical instruction in the works also he would rapidly develop his knowledge and usefulness. Lads of 14 who intended to become apprenticed to one or other of the shipbuilding or engineering trades could be given two years' special instruction in the school in such subjects as would ultimately prove of service to them in following their trade. In the selection of the subjects for special study the educational authorities could obtain valuable assistance from employers or their managers. We are glad to note that Messrs. Barr and Stroud have suggested such a course to the Glasgow School Board. In their letter the firm stated that as they were of opinion it would be to the advantage of apprentices that they should stay at the day schools until they were at least 15 years old, the firm, provided the year spent at school from 14 to 15 was devoted to subjects specially suitable for and interesting to engineering apprentices, had resolved to institute scholarships on the following conditions: (1) The scholarships would be 10 in number, tenable for one year, of the value of 10*l.* each; (2) they would be awarded to boys of the age of 14 recommended by the headmasters of certain selected schools, certified as medically sound, and approved by the firm; (3) they would be tenable at a school in which a course of instruction in mathematics and practical physics suitable for engineer apprentices could be followed; (4) the boys, before taking up the scholarship, would sign an agreement to serve five years' apprenticeship with the firm to the trade of instrument making or of engineering. On the proposal of Dr. Dyer, the chairman of the Glasgow School Board, the letter and offer were remitted to a special committee for consideration and report.

That the subject calls for thought will be apparent to all interested in the future welfare of industry, and as a preliminary to the realisation of the increased efficiency of men and plant which it is admitted on all hands must be attained in the near future, it is well that a satisfactory answer should be found to the question: Are the present conditions under which the education and training of apprentices are being carried out such as to warrant the demand for that increased efficiency in the worker upon which the industrial future of the Empire so greatly depends?

TRADE CARD EXEMPTIONS.

STRONG representations have been made to the Government in regard to the trade card agreement, and as a consequence on Tuesday Mr. A. Henderson presided at a conference on the scheme. There were present the Minister of Munitions, the Minister of Labour, the President of the Local Government Board, Sir John Jellicoe, Sir William Robertson, and representatives of bodies who were parties to the arrangement. Among the strongest critics of the agreement are certain trade unions, while employers in various parts of the country have protested against it. Railway companies also urge that their efforts to release men of medical category A for military service are being thwarted by agents of the unions parties to the agreement, and that many thousands of young men are thereby lost to the army. The trade card agreement was entered into at the end of last year by the Government and the Amalgamated Society of Engineers. Subsequently it was extended to 24 other craft unions, such as the Boilermakers, Steam Engine Makers, Toolmakers, Iron Founders, &c. The essence of the arrangement is that the members of the several unions should enrol as War Munition Volunteers, whereupon they are to be provided with a card of exemption from military service. The extraordinary feature of the agreement, however, is that while the form of the cards is authorised by the Army Council they are issued by the various trade unions. Possession of a card carries absolute exemption from military service, no matter whether a particular man can be spared by his employer or not, and the Army Council have instructed all recruiting officers that no man who produces a trade card shall be removed from his work without specific authority from the War Office, "which"—says the agreement—"will not be given without reference to the Minister of Munitions and the Executive of the man's union."

The question naturally arises as to why the Government should have sanctioned such an arrangement. We gather that it was in order to secure the co-operation of the trade unions in obtaining men for the army—the provision of skilled mechanics for the forces having been undertaken by the Ministry of Munitions. If we are correct in this assumption, it is certainly a matter for comment that employers of labour should have been entirely ignored. The trade unions pledged themselves to "do their utmost to provide the Ministry of Munitions with skilled men, who will undertake to serve, at the choice of the Ministry, either in the Artificers' Corps in the Army or as War Munition Volunteers in civil life." But the employer of men selected for either purpose does not figure as a party to be consulted or whose convenience should be considered. Possibly the agreement might have worked in the manner anticipated by those responsible for it had men been anxious to join the army. Unfortunately the majority seem to have been more desirous of obtaining exemption, and, it being in the power of the district

secretary of the various unions to issue trade cards, there is no doubt that the scheme has miscarried. In other words, it has been abused. On this point we may quote the views of the secretary of a trade union which is not a party to the trade card agreement. Speaking in the House of Commons, Mr. J. H. Thomas, M.P., the secretary of the National Union of Railwaymen, said that circulars and pamphlets were being issued stating "If you want exemption, join our union." He also said that unless a change were made there would be trouble because of what is happening in the large engineering shops every day, where the men are saying, "Here is Smith, an engineer, given a card of exemption. I also am an engineer, but because I do not happen to be a member of a particular union I cannot be exempted and Smith can." We will not speculate as to whether Mr. Thomas was more desirous of securing the abolition of the trade card agreement or its extension to his society. The point is that what he said definitely indicated abuse of the trade cards. This was confirmed by Mr. Pringle, the member for North-West Lanark, who said that the agreement was giving certain trade unions the means of recruiting members; while Mr. Thorne added that "there are men belonging to semi-skilled trades who are working side by side with the men that belong to other unions, *doing exactly the same kind of work*, and the men who belong to other organisations are getting cards of exemption." A somewhat half-hearted defence of the agreement was made by Mr. Kellaway, Parliamentary Secretary to the Minister of Munitions, but his remark that the scheme was not to be regarded as similar to the laws of the Medes and Persians was at least significant. The new scheme is to be explained to-day to a further meeting of other trade unions concerned in the output of essential munitions of war. We would suggest that employers of labour are also entitled to be consulted. It is not merely a question of feeling between craft and industrial unions, but of finding the best means of securing men for the army without curtailing the output of munitions. With that object, employers should be invited to express their opinions. Perhaps the most effective scheme would be to revise the list of scheduled occupations and raise the age limit for exemptions. Whatever is done, it must provide for the release of young men first. We understand that railway employees are released on this basis, and some arrangement of the kind might be applied to engineering works. The railway regulations provide that when it is found at any place that a man of any particular grade or position can be spared, the youngest man fit for foreign service shall be first chosen from the same grade and from the same station or depôt at which the man can be spared. If there is no single man available, the married man with the fewest children under 14 years of age is to be selected. In cases in which the number of children under 14 is equal, the youngest man must be selected. This formula could not be applied to engineering works, as it stands, but its adaptation should be practicable and reasonable.

THE CORROSION OF CONDENSER TUBES.

IT is common knowledge that the committee originally appointed by the Institute of Metals to investigate the corrosion of condenser tubes has been reconstituted, and now includes representatives of the Admiralty and the Board of Trade, as well as members appointed by some other societies and corporations specially interested in this matter. The earlier researches were conducted at Liverpool by Mr. (now Captain) G. D. Bengough, in such intervals as his normal work at the university permitted. On the reconstitution of the committee, however, substantial financial aid was promised from national sources, on condition that the work should be pushed forward under the direction of a "whole-time" investigator, a post which was naturally offered to Captain Bengough. The research is now being conducted under ordinary working conditions at the Corporation Electricity Works, Brighton, whilst the laboratory investigations are being carried out at the Royal School of Mines under the immediate direction of Captain Bengough. At Brighton a set of eight small condensers, each containing 12 tubes, 3 ft. long, are being run in parallel, both with each other and with one of the main condensers at the power station. The cooling water is obtained from the sea, the station being situated on the inlet at Shoreham. The tubes in the several small condensers are in each case of a different material, and, for the purposes of comparison, 16 of the tubes in a main condenser of the power station have been replaced by special tubes of four different alloys.

A special interest attaches to the installation because the power station condensers have been fitted with the Cumberland system of tube protection, which is effected by maintaining an electric current between the tubes and the electrolyte in such a direction as to inhibit corrosion. No tubes or materials are tested at Brighton until preliminary tests in the laboratory have given promise of results justifying the additional expense. The work so far accomplished has shown that corrosion may be started by defects in the tube arising in the course of manufacture. In the case of brass tubes the presence of a "spill" inevitably leads to erosion. This "spill" originates in a blow-hole against the sand core of the casting from which the tube is made. In the process of drawing this hole is deformed into a long groove, which is covered with a tongue or sliver of metal. Air collects in the space underneath this "spill," and whenever air collects on a brass tube immersed in sea water corrosion appears to be inevitable. Each tube is very carefully examined for internal flaws before being tested at Brighton, and the position of each is carefully recorded. Not all surface defects, even in brass tubes, appear to give trouble. An open groove, free from the long covering "spill," appears to matter little. The "swarf" holes are an example of this. These are produced by a neglect to completely clear the tube blank from every bit of swarf after boring and before drawing. The pits produced by these particles of swarf appear to matter little.

A point now being investigated is whether the presence of oxide in the tube is deleterious. To this end a number of oxide-free brasses have been prepared from cathode copper and Brunner-Mond zinc, melted in an atmosphere of hydrogen. The molten metal was not cast, but allowed to set in the crucible, which was cooled from below, so that the gases occluded on solidifying should not be entrapped. The whole of this operation was conducted in an atmosphere of hydrogen, and the tubes have been prepared from this oxide-free metal by the Broughton Copper Company. These tubes are now under test, but as yet it is uncertain whether they will show any superiority.

Amongst the tubes being tested are those containing 2 per cent. of lead, introduced by the Muntz Metal Company some few years ago. Since the lead does not form a solid solution with the rest of the alloy, but separates out in small spicules, it might have been anticipated that the presence of this free metal would give rise to local electrolytic effects and consequent corrosion. It appears, however, that this does not occur; the lead forms an adherent basic salt, which spreads over the surface and appears to protect it from further action. Another metal under test is an alloy of 10 per cent. of nickel with 90 per cent. of copper. So far this has proved quite immune to attacks in the laboratory, although the tubes furnished have had such rough interiors that when placed in a sea-water bath they immediately cover themselves with air bubbles. When similar bubbles collect on brass a white oxychloride of zinc is deposited, which acts as a catalytic agent, taking up chlorine from the sea water and passing it on to the zinc, with the result that the metal is dezincified. The resistance of the 10 per cent. nickel alloy is the more notable in that failures are reported to have occurred with tubes made from a 20 per cent. nickel alloy and from a 2 per cent. nickel alloy. Another interesting alloy under observation is one of copper with 7.8 per cent. aluminium. Preliminary tests with this have proved promising, and it is hoped to get still better results with oxide-free metal. The specimens so far tested have not been free from oxide, and have been found liable to a very curious attack consisting of small pinholes, which deepen rapidly. Elsewhere there appears to be no corrosion at all.

An American report having stated that the resistance to corrosion is improved by annealing the metal at a temperature just high enough (about 400 deg. C.) to secure recrystallisation, the point is being thoroughly investigated, the annealing being effected in an electric furnace which can maintain indefinitely four tubes, each 4 ft. long, at the desired temperature within a range of some 4 deg. C. Other tubes are being annealed at a temperature of 600 deg. C. before the test. This temperature destroys the effect of cold-working, which is commonly supposed to favour corrosion.

The experimental condensers at Brighton are of the type already illustrated in ENGINEERING, vol. xcvi, page 339. The temperature on the steam side of the tubes differs much from point to point. The middle of the tubes, immediately under the steam inlet, is kept clear of air by the inrush of the steam, and the tube is consequently hot here. At the end of the condenser, the steam being more stagnant, air collects round the tubes, materially lowering the temperature. Again, the tubes at the bottom are colder than those at the top. It has been observed that the local temperature of the tube appears to have a marked effect both on its liability to corrosion and on the kind of corrosion set up.

The investigation is undoubtedly one not merely of national but of international importance, since the cost of replacing condenser tubes aggregates annually to an extremely large figure. It is to be hoped that the research will be pushed to a successful conclusion as rapidly as the conditions permit. Since, however, accelerated tests are considered unreliable, the investigation must necessarily require some years for its completion, but interim reports of high value will undoubtedly be issued from time to time.

THE LATE LIEUT.-COLONEL J. H. WESTERN, C.M.G., LATE R.E.

THE death took place on Monday, April 2, at Hurstpierspoint, Sussex, of Lieut.-Colonel James Halifax Western, C.M.G. (late R.E.). He was gazetted to the Royal Engineers from Addiscombe and went to India in 1862, where he was engaged on irrigation work. He was superintending engineer of the head works of the Lower Ganges, Betwa and Sirhind Canals, and chief engineer from 1883–5, when he left India to take up work in Egypt under Sir Colin Scott Monorieff. On his advice the work of reconstructing the Delta barrage was undertaken, and he was the engineer responsible to the Egyptian Government for the execution of this most difficult work, which many eminent engineers had considered impossible; in fact to Colonel Western must be given the sole credit of converting the old useless French barrages into the effective works they now are, and on which the Delta irrigation and the valuable cotton crops depend. He retired from Egypt in 1890 on account of ill-health, just before the completion of this work.

On his return to England, Colonel Western was made inspecting engineer to the Egyptian Government, which post he held till 1909. He was the first to suggest to the late Lord Kitchener the advisability of constructing the desert railway from Wadi-Halfa during the Sudan campaign.

Colonel Western retired from the Army in 1886, and was awarded the C.M.G. in 1888 and the First Class Medijie in 1909. He married, in 1869, Caroline Sophia, youngest daughter of the late Mr. Guy Atkinson, of Cangort, King's County, and leaves two sons and a daughter.

MOTOR PLOUGHS AND AGRICULTURAL TRACTORS.—Messrs. Petters, Limited, are making preparations for the erection of a factory at Yeovil for the manufacture of motor ploughs and agricultural tractors at the rate of 100 machines per week. They have designed a new type of two-stroke engine for this work, which operates on common paraffin oil, and they expect to commence deliveries in August of the present year.

INCORPORATED MUNICIPAL ELECTRICAL ASSOCIATION.—The twenty-second annual general and other business meetings of this association will be held on June 21 and 22, at the Institution of Civil Engineers, Great George-street, Westminster, when Mr. F. M. Ling, city electrical engineer, Norwich, will deliver his presidential address. A paper on "Individual Interests in Municipal Enterprise" will be read by Mr. J. Horace Bowden, borough electrical engineer, Poplar, and one on "Fuel Economy," by Mr. J. A. Robertson, borough engineer, Salford.

THE INSTITUTION OF NAVAL ARCHITECTS.

(*Continued from page* 306.)

IN our last issue we reported the discussions before the Institution of Naval Architects on Wednesday, March 28, in the morning and afternoon. We now proceed to the evening meeting of that day.

STRUCTURE OF MILD STEEL.

The first paper taken at the evening meeting on Wednesday, entitled "Strength and Inner Structure of Mild Steel," was contributed by Professor W. E. Dalby, F.R.S. In it the author announced a simple relation which he had found between the carbon content and the strength of certain types of steel. Provided that the steel is normal in composition and provided that it has the normal pearlitic structure, Professor Dalby finds that its strength when plotted, against the carbon content, gives a straight line. The paper is reprinted on page 319 of this issue.

The discussion was opened by Professor H. C. H. Carpenter, who said that metallurgists and chemists were glad to welcome a new worker in micrography who approached the subject from a fresh standpoint—that of the engineer. At the outset he must congratulate the author on the excellence of his technique. The author had stated in his paper that pearlite consisted of 13.5 per cent. of cementite and 85.6 per cent. of ferrite. This was a weight ratio. Taking the density of iron as 7.86 and that of cementite at 7.07, the corresponding volume ratio was 6 to 1. The author, in Fig. 9 of his paper, showed how the strength of iron was dependent on the amount of pearlite present. From his diagram pure iron would have apparently a strength of some 16 tons per square inch. A remarkable confirmation of this estimate would be found in Dr. Stead's paper to the Iron and Steel Institute read last September. This paper was a most comprehensive survey of the effect on iron of additions of other elements, and amongst these carbon took, of course, a prominent place. Although carbon-free iron was not examined, yet an extrapolation of Dr. Stead's results indicated that its strength would be about 17 tons. Personally, he would have been inclined to draw Professor Dalby's line a little higher, since there were only two points shown below his line and five above, and this would make the agreement with Dr. Stead still closer.

The relation established by the author was very important, and the evidence must be accepted as true for the particular class of steels considered. It only held, however, if the carbon were present as pearlite. Pearlite was inherently unstable, and on very prolonged heating the plates of carbide and iron would lose their laminar structure and ball up.

In mild steels iron was present in great excess, and on very prolonged heating this iron would draw to it the iron from the pearlite, leaving the cementite nearly pure. In this condition the strength tended to approximate to that of pure ferrite, being greatly reduced, although as much cementite was present as at the outset. Moreover, the linear law given by Professor Dalby only held if manganese, phosphorus and similar impurities were present in normal amounts. Nevertheless within the limits stated by the author the law was established. Referring to Fig. 11 of Professor Dalby's paper, showing autographic diagrams for different kinds of steel, the author observed that a new class of material seemed to make its appearance when more than 0.75 carbon was present, and there was in fact a change in constitution in passing from a low-carbon to a high-carbon steel. With less than 0.9 carbon present structural ferrite was obtained on annealing. With higher carbon contents, annealing gave eutectoid steel and no ferrite. Incidentally, he might say that, so far as he knew, the author was the first to measure the thickness of the pearlite plates. In his reference to wrought iron the author had brought forward a question which was still a puzzle, viz., that the carbon present in wrought iron had not the same structural form as it had in mild steel. The latter was melted and cast, thus providing an opportunity for the iron and carbide to separate no cooling. In making wrought iron, however, the carbide crystallised out in a different combination than in the case of steel, and no pearlite was to be found in wrought iron.

Dr. W. H. Hatfield, who spoke next, said that on the whole he was in almost full agreement with the general explanation given by the author as to the internal architecture of steel. The important law advanced as to the connection between pearlite and strength was good and correct within the limits stated. If a series of steel were taken, containing more and more carbon, and with the pearlite in the same condition, then the author's rule was valid, but the limits within which it held were very narrow. Naval architects had to deal not with small samples of steel, but with masses up to as much as 40 tons. Such masses would not respond either to work or to heat treatment in the same way as smaller ones would, and the speaker would accordingly again emphasise that the proposed law could only be taken as academic, applicable under strictly limited conditions. Moreover, steel castings were the pearlite was in itself much the same in both, but it now constituted the network, whilst with Professor Dalby's steels the network was of ferrite. The pattern, therefore, was very important, and unless attended to, the proposed linear relationship between the ultimate strength and the proportion of pearlite present would be vitiated.. The question as to how carbon occurred in wrought iron was still a matter of debate, but the speaker thought it possible that the ferrite in this case did contain a little carbon in solution, a view which Benedicks had supported by various considerations. It was unsafe to assume that in testing a homogeneous piece of iron each individual crystal would behave in the same way. No one had yet shown why pearlite should have a strength of 62 tons. Pearlite contained, as stated, some 13 per cent. of a hard constituent embedded in a soft one; that this should increase the strength four times was a very astonishing fact. In conclusion, he would like to add his own to the author's testimony as to the value

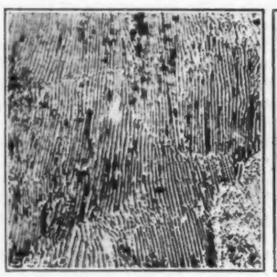


FIG. 1. Typical Pearlite, etched and magnified 600 diameters.

FIG. 2. Structure of Wrought Iron, etched and magnified 60 diameters.

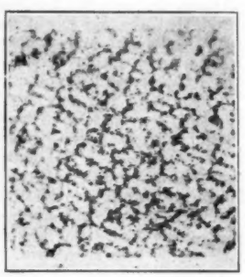


FIG. 3. Typical section of Steel Casting after being properly annealed, etched and magnified 9 diameters.

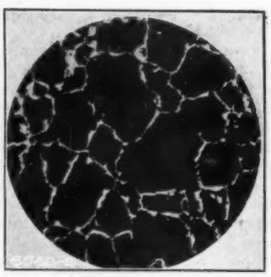


FIG. 4. Typical Structure of Steel Forging, 0.5 to 0.6 C, etched and magnified 30 diameters.

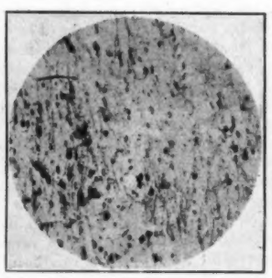


FIG. 5. Effect of Tension on Ferrite Crystals of Wrought Iron, etched and magnified 60 diameters.

FIG. 6. Deformation of Composite Structure under Tension, etched and magnified 60 diameters.

used as well as steel forgings, and he had brought with him some slides which showed not only the structure of the pearlite and the ferrite, but the pattern they made when examined under low powers. This was a matter of great importance.

The range through which the patterns might vary was shown in the annexed micrographs, Figs. 1 to 6. Here Fig. 1 represented a good specimen of pearlite and Fig. 2 the structure of wrought-iron. In Fig. 5 the effect of tension on the ferrite crystals of this iron was indicated, whilst similarly Fig. 6 showed how a composite structure deformed under tension. The material here was the same as in Fig. 3, which showed the pattern obtained after suitable annealing with steel castings having from 0.3 to 0.35 of carbon. A typical structure of a steel forging with from 0.5 to 0.6 carbon was shown in Fig. 4.

Professor Dalby had estimated the strength of pearlite at 62 tons and that of ferrite at 16 tons, and with this estimate the speaker agreed. The strength of a steel containing pearlite would, however, be very different if the pearlite formed the matrix and the ferrite balled up. The structure met with in steel castings was entirely different from any of the structures shown by Professor Dalby. If the ferrite formed the matrix in which the pearlite was embedded the whole of the lattice would have to yield before failure. After annealing an entirely different structure was found, although of Carpenter's temperature-concentration diagram for carbon in iron, the importance of which had not now been appreciated till quite recently, but it was coming into its own.

Mr. C. E. Stromeyer, in connection with the author's remarks on the difference found in the behaviour of high and low carbon steels, said that in certain torsional fatigue tests he had found that the specimen fractured as indicated in Fig. 7 when the carbon content was high, whilst with soft steels the fracture occurred as shown in Fig. 8. As to the effect of carbon on the strength of steel, he thought that the nitrogen content could not be neglected. The effect of a given dosage was ten times as great as that of carbon. If the author's specimens were open-hearth steel the nitrogen present would be about 0.004 per cent., and a fairly uniform line would represent the alteration of strength with changes in the carbon content. Bessemer steels, however, contained about 0.024 per cent. of nitrogen, and the tenacity was 4 tons or 5 tons per square inch more than indicated by the author's diagram, although the quality of the steel was lowered in other respects. In a paper read before the British Association he had attempted to test Guest's law, according to which the risk of failure was proportionate to the difference of the principal stresses. Hence in a tensile test the yield-point should be twice as high as under torsion.

He had found that the results were most consistent if the drop of the lever of the testing machine was taken as indicating the point of failure. He had, further, found in these experiments that there was no apparent connection between the elastic limit of a bar and its chemical constitution, nor was there any apparent relationship between this constitution and the true stress at fracture, which was equal to the then load on the bar divided by the area of the cross-section at the instant of breaking. On the other hand, there was a clear relationship between

Fig. 7.

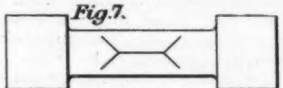
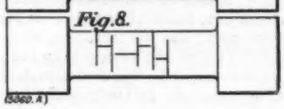


Fig. 8.



the tensile strength as ordinarily measured and the composition of the bar. This was remarkable and unsatisfactory, since the tensile strength as usually estimated was an absurdity. To obtain it the highest load carried was divided by the original section of the specimen, no allowance being made for the reduction of area by the plastic flow. The speaker's own formula connecting the strength of steel with its chemical composition gave excellent results, if allowance were made for the nitrogen content.

In reply, Professor Dalby expressed his gratification at the interest shown by the metallurgical experts who had spoken of the work of a mere engineer. He could not throw any light on the question raised by Dr. Hatfield as to why pearlite gave the strength it did. Some of the diagrams exhibited by that speaker referred, he understood, to castings, and the speaker would certainly not apply his formula to these. He was, moreover, fully aware of the limitations imposed by practice.

Annealing, in particular, was often very badly carried out. The metal was heated under no kind of control, and then thrown simply on the floor to cool. This did not constitute proper time and temperature treatment. All he claimed for his law was that if the steel could be treated so as to form pearlite in the laminar state the strength corresponding to a given carbon content could be obtained from his diagram. If the strength demanded lay above his line, he would consider the specification a stringent one. Mr. Stromeyer had raised an interesting point in connection with the way in which high-carbon steels fractured under torsional fatigue. He would not enter into the question as to the effect of nitrogen, Mr. Stromeyer's views on which were well known.

Strength of Pin Joints.

A paper on "The Design of Pin Joints based on Ultimate Strength" was next read by Lieut. Walter A. Scoble, R.N.V.R. In this paper the author described the results of experiments made to determine the proportions of the pin joint of greatest efficiency, that is to say, of least weight for its strength. We shall publish this in full in a future issue.

The discussion was opened by Professor W. E. Dalby, who said that the author's paper drew attention to a question of importance in structures of all kinds, where it had always been somewhat of a paradox that the yielding of the metal led to a development of additional strength. If we could calculate the real stresses to which structures were exposed we could use harder steels. The reason that we were, for many purposes, restricted to the use of mild steels was due to the necessity of having a material capable of yielding locally so as to distribute local concentrations of stress.

Professor Margetson, who spoke next, said that some years ago he had had to design the pin joints for the pull rods of brake gear, and adopted an arrangement similar to that indicated in Fig. 9. The hole was central and the head of uniform thickness. On reading the paper presented by the author and Professor Coker in 1913 it appeared that this design of the eyes was all wrong, since it was shown that under the conditions of the experiments there described the stress was about three times the average at the edge of the hole, and zero at the outer edge of the eye. The rational cross-section through the eye should from this point of view have been somewhat as indicated in Fig. 10. From the paper just read, however, it would appear that the original design was quite satisfactory. Whatever pull would smash the eye would smash the rod, and this was all that was required. In order to use the formulas for design proposed in the paper, it was necessary to know the ratio of the ultimate strengths in shear, in tension, and in compression. The last-named quantity was difficult to determine. The author had tried to find the crushing strength by the Brinell ball test, but although this test gave a fair indication of the tensile strength of a metal, it was, as the author had found, unsuited for determining the crushing strength. The latter could, however,

Fig. 9

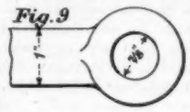
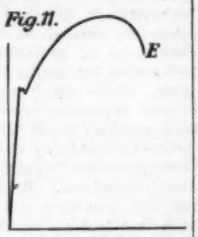


Fig. 10.

Fig. 11.



in the case of mild steel, be determined indirectly from a tensile test. Take, for example, the ordinary autographic stress strain diagram as indicated in Fig. 11. From it read the load at the moment of fracture indicated by the point E. If, then, this load were decided by the reduced area at fracture, the result would be equal to the crushing strength of the material. On the speaker's suggestion Lieut. Scoble had made this test on one of his steels, getting a figure of about 48 tons for the crushing strength, whilst a determination made by the speaker on a similar steel some years ago gave 49 tons. The author had in his paper taken 40 tons as the crushing strength, but admitted that this was somewhat low. Generally speaking, in mild steels the ultimate crushing strength was about twice the ultimate resistance to shear.

In reply Lieut. Scoble said that he had found that metal drawn until it had a tensile strength of 150 tons per square inch had still sufficient ductility to provide for the relief of local concentrations of stress, and he thought that perhaps the importance of ductibility had been overrated. In experimental work the aim was commonly to detect the first sign of failure, and this depended on the yield. If, however, we wished to know the real factor of safety we must employ the ultimate strength. He had, as stated by Professor Margetson, adopted a somewhat low value of the crushing strength in proportioning his joints. This, however, was reasonable, as it would not be fair to assume that in the conditions of use the full crushing strength would be developed.

Thursday's Proceedings.

On opening the proceedings at the morning meeting of Thursday, March 29, the secretary read the names of over one hundred new members, all of whom were elected in addition to the large number elected on the preceding day.

The chairman, the Marquis of Bristol, then said he wished to put before the meeting a matter which he felt sure would meet with every approval. He referred to the message which had been received on the preceding day from the First Sea Lord complimenting the Institution upon the way in which the members had risen to the occasion and had assisted the Admiralty and the country in carrying out their work. He felt sure the Institution felt grateful to Admiral Jellicoe for his message, and he moved a hearty vote of thanks to him for his appreciation.

Sir Archibald Denny and Mr. Robert Duncan, M.P., seconded the vote, which was carried by acclamation.

Further Experiments Upon Wake and Thrust Deduction.

The first paper taken was one by Mr. W. J. Luke, on "Further Experiments upon Wake and Thrust Deduction." It was read by the author. We reproduce it on page 339 of the present issue.

The discussion was opened by Mr. G. S. Baker, who said he was sure he voiced the general opinion when stating that the author's contributions had been found of great use for many years to all ship designers. He would like to ask for more data on a few points, in the first place with regard to the speeds chosen in the tests with a different model; the full model and the fine model were run at different speeds, and therefore at a different wave phase of the balanced stern system. This had an effect on the resultant wakes obtained by the experiment. In all boats of this type the higher the speed the lower was the wake, which explained, in part, the fact that the smaller block-coefficient vessels had smaller wakes and thrust deductions. He asked whether the clearance of the propellers, when the extreme fullness of stern was put on, was the same, because clearance was really as important as fullness of stern, and when the stern was filled out clearance was reduced, this explaining the high wakes of the fuller models. By referring to the author's Fig. 1 the results for the model D showed higher wakes for the vessel having the smaller diameter screw, and this did not accord with his (the speaker's) experience in analysing a large number of trials. He was inclined to think that 7-in. screw had been written for 5-in., and *vice versa*. With a smaller diameter screw there was a smaller wake, smaller thrust deductions and smaller hull efficiency; the curve was, therefore, different from that shown in the author's Fig. 1.

Sir E. H. Tennyson d'Eyncourt thought it would be useful if he gave the experience of an actual case tried on a full-size model, although dating some fifteen years or so ago. The case occurred at the Fairfield yard, and, as far as he could recollect, these were the points. Two ships had nearly horizontal bossed and spectacle framing, but, in service, the ships did not give quite the expected results in regard to economy of fuel, and when one returned he (the speaker) suggested to Dr. Elgar to alter the angle of bossing. This was altered up to 45 deg. Careful progressive trials were made with both the old and new bossings and the results were very promising, particularly at the higher speeds. But the improvement was not progressive, because at the somewhat low speed the curves actually crossed, showing that the horizontal bossing was better at some speeds than the more angled bossing. Perhaps the most valuable evidence of improvement was in the fact that after one ship had been altered and placed in service, the saving of coal was such that they had the sister ship altered in the same way.

Professor Welch endorsed what Mr. Baker had said, and he also wished to endorse the author's thanks to Messrs. John Brown and Co., Limited, Clydebank, for the help they had given in the matter of the experiments. It would seem to him (the speaker) that, in Mr. Luke's desire for brevity, he had not emphasised the point where he referred to the factor in the hull efficiency which denotes wake gain, the author adding that there was in fact no such wake gain, though the idea recurred from time to time. Professor Welch said that if the author started off by saying that there was a definite wake gain he (Professor Welch) took it that there was such a wake gain. It was not an unreasonable term to use, if limited by the assumption that the revolutions remained the same. He thought Mr. Luke was probably more concerned with the maximum return from the wake current, and, as he had said, the idea had occurred that it was possible to pick up some of the energy in the wake, and to return it to the thrust block of the ship. It was clear that with less slip there would be an alteration in the revolutions, and the sole difference between that case and that in which the propeller was encountering the wake, was this, that the propeller was working at a somewhat different slip, but the efficiency would not be affected to a sensible degree. If the conditions happened to be such that the propeller was immediately behind the ship, the propeller would be working at its maximum efficiency, and there would be, theoretically, a slight gain as compared with no wake, but it might easily be just in the opposite direction.

Mr. A. T. Wall then read a note by Mr. Gibson,

the latter stating that Mr. Luke's paper should enable the naval architect to arrive at a close approximation of the power required to propel a given vessel at a given speed. It would be recalled that last year Sir Archibald Denny stated that his firm had done something in the direction of measuring actual propeller thrust. Mr. Gibson's firm had years ago experimented with a form of hydraulic thrust meter, and the results had been communicated to the Institution. The recorded thrust was found to be in excess of that estimated. Since then the firm had applied the principle to a geared turbine vessel, and Mr. Gibson hoped to give further particulars in due course. He could say, however, that indicator diagrams were not needed, as in the case of the reciprocating engine, which, of course, had a fluctuating thrust. The pressure gauge sufficed for the steady thrust of the turbines. The data so readily obtained in a full-sized ship would be, he thought, valuable in experiments on a toy scale, where the slightest error or disturbance was multiplied a thousandfold. The case quoted by Mr. Gibson was on a big scale, there being 25,000 h.p. on one shaft, and a steady pressure of over 70 tons.

On his own behalf, Mr. A. T. Wall said the author had stated it was an essential fairly to assess the elements of a propeller in the stage of design, and the investigation was not for showing where a propeller was to be placed so as to get the maximum return from the wake current. But he (the speaker) thought that had an important bearing on the subject. If the position of the propeller relative to the ship were not determinable, the wake fraction might prove wrong. He added that he found in the author's Table 2 a remarkable agreement in the wake factor of models and of full-size ships.

Sir Archibald Denny, who followed, referred to the question of the negative value of the wake, remarking that in fast destroyers it was quite common. The author's statement to the effect that when many data had been collected they had to be carefully analysed was quite true. The difficulty with the propeller was that the conditions were very complicated. At his tank, the speaker said, they started with an immediate resistance. They were still working at their screw experiments, but did not now carry out many experiments with models. They were now at their third screw apparatus. The first apparatus was much the same as Mr. Froude's original method. The second was of a kind in which one, two, three or four screws were used, each registering separately its own thrust and torque; the last one was more convenient, because results were more quickly obtained from it; they had one motor, and by gearing they worked one, two or three screws; they obtained the torque and thrust for the combined screws, but the apparatus was, of course, better applicable to one or two screws, as with three screws separate analysis was necessary. The new apparatus gave very consistent results. There was no trouble in arriving at the resistance, wake and efficiency at the same time. The experiments referred to by Mr. Wall, in which there were 25,000 h.p. on one shaft and a steady thrust of over 70 tons, were very interesting. He (the speaker) had experimented with an ordinary cargo boat to see what could be done. Undoubtedly, if one could have an instrument as easily applicable as a torsionmeter, it would be a great advantage to everyone, serving as it would to indicate, in every case, shaft horse-power and thrust. His firm had designed an instrument, but could not induce the engineers, who were fearful of it, to put it on. An hydraulic cylinder on the thrust block was a most direct way, but it involved a good deal of expense, and, after the experiment, was of no further use.

Mr. W. J. Luke expressed in reply his gratification at the reception which had been accorded to his paper. The subject dealt with was not one which would lend itself to discussion on the spur of the moment. If any point came out and it were put before him, he would endeavour to reply fully in writing. With reference to the value of full-size as compared with toy experiments, he (Mr. Luke) had always endeavoured to emphasise that these experiments formed a sort of sieve for sifting the results of practical trials. His model results were simply to serve as a gauge for comparing with full-size results.

On the motion of the chairman the author was awarded a hearty vote of thanks for his paper.

On Some Experiments on the Influence of Running Balance of Propellers on the Vibration of Ships.

The next paper taken was the one having the above title, contributed by Mr. J. J. King-Salter, R.C.N.C., who is now in Australia. It was read by the secretary. We reproduced it in full on page 297 *ante*.

The discussion was opened by Mr. S. Barnaby, who found that the paper was an extremely creditable piece of work. The author, he added, was a naval architect who was doing the country's work in the Colonies. Naval architects usually left the making of the propellers to the engineers, but Mr. King-Salter had found that the propellers delivered to him were not satisfactory, and he therefore devised an apparatus for the dynamical balancing of propellers, and also an ingenious apparatus for testing the amount of vibration of a ship, about which no two opinions were alike. These apparatus served their purpose well. He (the speaker) would have hardly expected that with propellers made by the best makers it should have been necessary to finish them in the way the author had pointed out. Mr. King-Salter said that usually all that was done in this country was to machine the face and calibrate the backs as carefully as possible. It was the speaker's practice, if he was particular about the propeller, to go to the manufacturers and test the calibration on the section and over the blade, and he was satisfied with that, but the author pointed out that we could no longer accept that as sufficient. If the propeller makers could machine the propeller at the back as well as at the front, it should be perfect. Fig. 9 in the paper showed the vibrating disc employed to ascertain the extent to which it was necessary to alter a propeller in order to balance it dynamically, the white disc, oscillating through considerable angles, showed the propeller materially out of balance, while the next photograph, in which the white disc was in no way elongated, showed that the balancing was practically perfect. Sir E. H. Tennyson d'Eyncourt had not been able to remain at the meeting, but he had expressed his thought to him (the speaker) to the effect that the Royal Corps of Constructors could be proud that one of their number had done such good work and had been able to present it to the Institution.

Sir George Greenhill, who followed, said that dynamic balance in the first place was secured by making the axis of rotation the principal axis of the body, and so long as the axis preserved a fixed direction that one condition was sufficient to prevent vibration arising from any centrifugal action. When the axis changed in direction, as it would in the case of a screw steamer by a change of course, or by a pitching motion among the waves, the further condition was required that the axis should be one of kinetic symmetry; in other words, all axes at right angles to the axis of rotation should also be principal axes. The effect mounted up very rapidly with the high rate of rotation employed in modern machinery, *i.e.*, as the square of the revolutions. In a flying machine, where the propeller was two-bladed, the effect, he was told, was remarkable as the machine altered its direction up and down, in the vertical plane, or right and left. At least three blades were required if a perfect dynamic balance was to be secured, as was shown in the author's diagrams. He (the speaker) had discussed the theory of vibrations set up as a result of incomplete dynamical balance in a report on gyroscopic stability which he had prepared for the Aerial Committee.

Professor W. E. Dalby was interested to see that the question of balancing propellers was attracting attention. The question of balancing had been brought prominently before the Institution some ten years ago, when, although static balancing was well understood, the balancing of couples was not generally understood and was left to itself. Attention was mainly given to the engines. The United States Navy once offered a prize on the best paper dealing with the balancing of engines. The chief engineer of the United States Navy made a mistake in entering for the competition. The chief constructor also entered, and won the prize, which led to considerable feeling on the subject. The chief constructor endeavoured to introduce the system of balancing adopted on this side, but the chief engineer was against the system, and appointed a sort of commission to examine all the papers written on the balancing of engines, and then attacked the balancing system adopted in this country—the Yarrow-Schlick-Tweedy system—and also attacked him (the speaker) for having brought this forward. The Americans quoted a report on an experimental system in the German destroyer S. 42, in which the engines were stated to be unbalanced and the boat vibrated. The Yarrow-Schlick-Tweedy system was then applied, and the boat vibrated worse. They had not, however, quoted the next part of the report, pointing out that on removal of the propeller there was no vibration, showing that the unbalanced effect had been due to the propeller and not to the engines. He had also pointed out that it was as important to deal with the balancing of the propeller as with the balancing of the engines, and this proved the importance of the paper. The speaker then alluded to the trouble with vibrations which he had had with an "accurate" grinding machine; he had been compelled to take this to pieces and to have it properly balanced. He also referred to the necessity of balancing locomotive engine wheels.

Mr. Thomas Bell, who followed, referred to Mr. Barnaby's remarks on imperfect propellers, sometimes produced by the engineer, and also to Professor Dalby's observations on engines balanced on the Yarrow-Schlick-Tweedy system, which, as was generally agreed, was as perfect a system as had been devised and sound in principle, and by its aid balancing was secured with the minimum cost to the engine. But even in ships in which the engines were balanced on that system the speaker's firm had experienced trouble, as, for instance, in the case of the Duke of Connaught. He showed on the blackboard how a propeller could be swept out differently. By doing this in the case of the Duke of Connaught admirable results were obtained, as Mr. Abell, who was present at the time, could testify. These results were also partly due to increasing the distance between the tip of the propeller and the ship. This was carried to extremes in other vessels, and the vibration had been practically eliminated, but speed had been lost, and the owners had to go back to a propeller having slightly greater vibration, when they regained speed. All tended to show, therefore, that there remained much to do still in the matter.

Mr. P. R. Jackson said that with the Tribal class of destroyers, when the propellers ran at 700 revolutions many difficulties with vibrations occurred, especially in the case of one vessel having a flat stern. He thought the trouble which arose might not be due so much to variations in the dimensions as to the composition of the material forming the propellers. To illustrate his remark he instanced a forging made of high-grade steel for a turbine rotor; this material was about as homogeneous as anything could be, but notwithstanding he had found it necessary to balance rotors dynamically and not only statically. It was difficult to find exactly where to take off and where to add weight.

Mr. R. J. Quelch, who followed, said that during the past years he had had many propellers to balance and had found that it was not a simple matter to balance them even statically. The face of the propeller had first to be trued, and the material at the back removed, in doing which the truth of the face had been altered. He asked whether Mr. King-Salter, after removing the material to produce balancing, had trued up the face again. He also asked whether alteration of pitch was not of more importance to the running of the propellers than the balancing, and whether when the three blades were not all of the same pitch the effect was not greater than that of want of balance. For statical balancing it was necessary to go over the face two or three times, but after trueing up the face to the pitch he had found the pitch diameter to have opened out ¼ in. The author had proposed to do away with statical balancing and to proceed with the dynamical balancing straight away, and he (the speaker) added that before the author obtained his balancing in that way, the class of ship for which

the propellers were destined would have time to get out of date.

Mr. Herbert Peters, speaking from the point of view of a manufacturer of propellers, said he had been greatly interested in the author's paper. The dynamic balancing of propellers was a matter which he had considered as a manufacturer. He thought it would be a long and costly process; it was one on which more information was still wanted. The author had not been the first to advocate the dynamic balancing of propellers, and he (the speaker) thought that Messrs. Burmeister and Wain could give the Institution information on the subject. He asked whether the dynamic balancing was to be done by the manufacturers of propellers or by the shipyards. It would seem to him (the speaker) that when the dynamic balancing was being carried out the propeller should be fitted on its actual shaft, for if, for example, the keyway was not fitted in the experimental shaft the propeller would give later on, on its actual shaft, different results from those obtained in the experiments. He asked whether the back of the blades could not be machined; this was, he knew, a difficult problem, but if the required machine could be designed, this machining could be carried out.

Fig. 12.

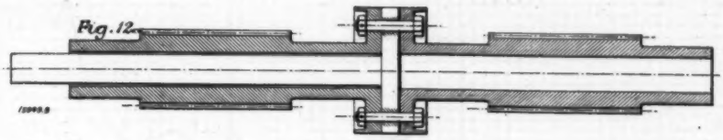


DIAGRAM SHOWING OPENING OF CONTACT ON PINION DUE TO TWIST.

Fig. 13. FLOATING FRAME.

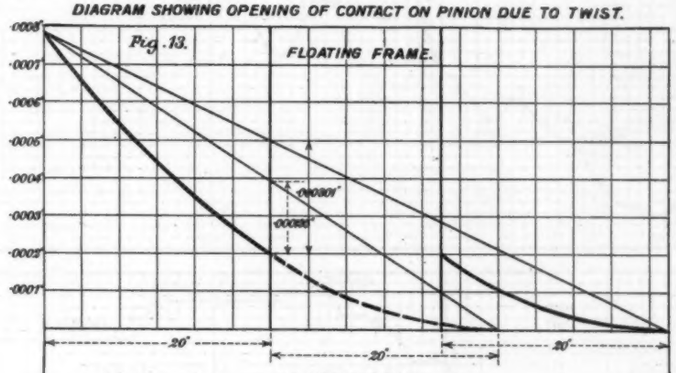


Fig. 14. CENTRAL DRIVE.

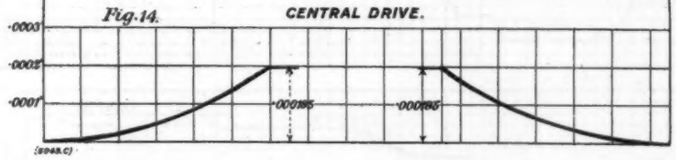


Fig. 15.

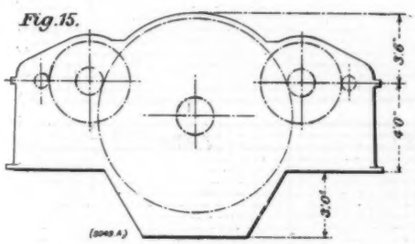


Fig. 16.

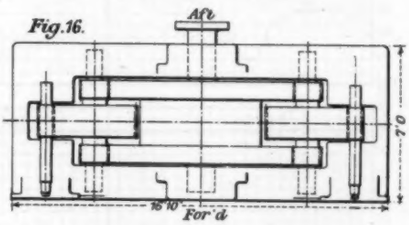


TABLE I.—PARTICULARS OF GEARS COMPARED.

Full power	2,900 S.H.P.
Turbine speed	3,860 R.P.M.
Propeller speed	75 R.P.M.
Power per pinion	1,450 S.H.P.

	Floating Frame Gear in Oil Tank Steamer.	Power Plant Company's Gear.
Pitch diameter, pinion—first reduction	5.114 in.	6.857 in.
Pitch diameter, wheel—first reduction	41 in.	45.143 in.
Face width —first reduction	20.5 in.	18 in.
Pitch diameter, pinion—second reduction	10.228 in.	13.333 in.
Pitch diameter, wheel—second reduction	66 in.	104.667 in.
Face width —second reduction	41 in.	20 in.
Pressure, lb. per in. face—first reduction	451	406
Pressure, lb. per in. face—second reduction	902	1,168
Power constant —first reduction	2.81	1.16
Power constant —second reduction	2.81	1.04
Length over base, fore and aft	11 ft. 2 in.	7 ft.
Breadth, athwartship	13 ft. 3 in.	16 ft. 10 in.
Superficial area, sq. ft.	149	118
Approximate weights, tons	40	35

On the motion of the chairman the author was heartily thanked by the meeting for his contribution.

THEORY OF WAVE MOTION ON WATER.

The last paper taken at Thursday morning's meeting, March 29, was the one on the "Theory of Wave Motion on Water," by Sir George Greenhill, who read it in abstract, wave motions being illustrated with the aid of small models presented by Mr. W. B. Croft, of Winchester, one apparatus showing analogous wave motion in the vibration of a chain rotated by a little dynamobile.

We shall report the discussion on this paper in our next issue.

REDUCTION GEARS.

At the afternoon meeting on Thursday a paper by Mr. J. H. Macalpine on "Marine Applications of Reduction Gears of Floating Frame Type" was read by the secretary. This paper is reprinted on page 321 of this issue. The secretary also read a note by the author stating that the oil-tank steamer referred to in the paper was now at sea, and the gear was reported to be working very satisfactorily.

The discussion was opened by Mr. Butler, who observed that in the only plants described by the author as having been in operation for a long time the power constant was low—as little as 1.68 in the case of the gear for the Commonwealth Steel Company. He also noted that the high-power constants recorded appeared to refer uniformly to overload conditions. For normal conditions of running the figures were little, if any, in excess of those adopted for rigid gears, which had been running satisfactorily for long periods of time. With ordinary care there was no excessive wear in the case of rigid gears. Examinations of such gears recently made showed that in point of fact the teeth did bear evenly over their whole lengths. Hence the majority of British engineers were inclined to question whether the advantages of the floating frame were sufficient to compensate for the greater complication inherent in the system.

Mr. H. H. Thorne said that his firm, the Power Plant Company, of West Drayton, had supplied the gears used by Sir Charles Parsons for the Vespasian and also the double reduction gear used for a rolling mill in Scotland. His firm had supplied a large number of such rigidly mounted gears, and from this experience it could safely be asserted that the minute errors of alignment, to which Mr. Macalpine had referred, were not in practice nearly as serious as the author supposed. In fact, most of the gears, after even a short run, showed a perfectly uniform bearing over the whole tooth surface in action. His firm's practice, he might add, was to remove by grinding any roughness of the tooth surfaces before putting the gears into commission. He believed that the inaccuracies of alignment could be kept within such small limits that the necessary adjustment could be provided by an automatic variation in the relative thickness of the oil film in the bearings, especially if the clearances were ample and the oil supplied at, say, 15 lb. pressure. He thought the author's claim that the floating frame corrected one-half to two-thirds of the torsional yield of the pinion was a fair one. The speaker would, however, like to call attention to Fig. 12, which showed an arrangement patented by his firm in 1911 by which the torsional yield was reduced to one-third that of a solid pinion. As shown, the pinion was hollow and in two parts, which were bolted on opposite sides of a flange which formed the end of a flexible shaft through which the drive was transmitted. In this way not only was the torsional yield reduced, as stated, but each half of the pinion had to take its due share of the total load. In Fig. 13 he had reproduced from ENGINEERING the author's diagram of the torsional yield of a pinion, and had added in Fig. 14 curves giving the torsional yield of the same pinion when constructed on the plan just described. He could not admit the author's third conclusion, that the power constant was a fair criterion for comparing gears. Instead of arguing the matter theoretically he would compare the author's data for the oil-tank steamer, with gears for approximately the same output and conditions now being made by his firm. These had ordinary rigid bearings and were without the advantages of the central drive. The comparative figures were as given in Table I. It would be seen that whilst his firm's diameters were larger than the author's, the face widths were less, particularly in the second reduction, so that the fore-and-aft length was but 7 ft., as compared with about 11 ft. 2 in. for the floating frame gear. The area occupied was 120 ft., as compared with 150 ft. The actual weight of the Macalpine gear was not given, but from the data available it appeared to be over rather than under

40 tons, whereas the weight of the rigid gears, including the shafting dimensioned to Lloyd's requirements, was but 35 tons. To summarise, with power constants of 1.16 and 1.04, as compared with Mr. Macalpine's figures of 2.81 and 2.81, the latter weighed 14 per cent. more and occupied 25 per cent. more floor space. The saving was largely due to care taken to eliminate all unsymmetrical stresses as indicated in the diagrammatic views reproduced in Figs. 15 and 16. The number of bearings had been reduced to a minimum, but nevertheless the bearing pressures were very light. This was due to the care taken in fixing the pitch-line diameters. It would, he thought, be obvious from the foregoing that marine gears could not be judged solely by their power constant, as defined by the author. The fourth conclusion put forward in the paper could not be disputed, but it did not prove that rigid gears with a central drive could not be made with the same power constant as floating frame gears if customers wished to have them.

Sir William E. Smith said he could not discuss the subject of the paper in detail as had been done by the previous speakers. On general principles, however, he thought there was much to be said in favour of the floating frame, which embodied Lord Kelvin's principle that unnecessary geometrical restraints should be avoided in all mechanical constructions. He remembered how in the early days of turbines, fitted for lighting destroyers, shaft fractures were frequent owing to the rigidity of the bearings, and the difficulty was overcome by introducing a type of bearing which allowed the shaft to adjust itself to a position of dynamic balance. Again, when rudder gears for battleships were first introduced with the top part some 7 ft to 8 ft. below water, the operating gear, at first fitted, gave rise to prejudicial fore and aft pressures on the pivots. Unnecessary restraints were removed and the trouble ceased. He was not enough of an engineer to say whether rigid bearings were preferable to the floating frame, but the latter did eliminate inaccuracies of tooth bearing, however arising. It was noteworthy that the scraper marks on the teeth were still visible after a floating frame gear had been running a long time. He noted that the last speaker said that the teeth of the gears supplied by his firm were ground up, a fact which seemed to show that more care was necessary than with floating frame gears.

The chairman, Mr. Sydney Barnaby, in closing the discussion, said that the author had not stated how many shafts were being used for the transmission of the 90,000 h.p. of the cruiser mentioned. If it was a four-shaft installation, he could state that equal amounts of power were being transmitted in this country through rigid gears.

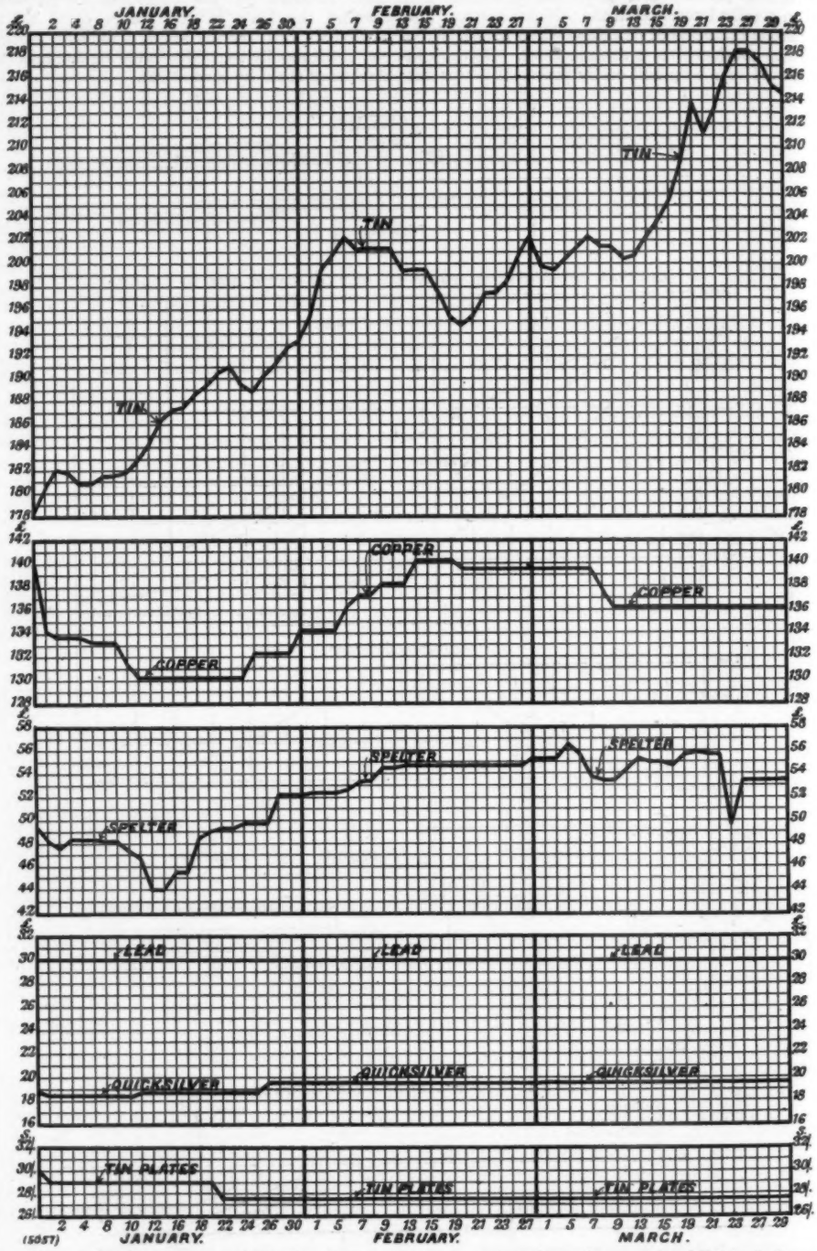
(To be continued.)

Laxton's Builders' Price Book.—We have received a copy of this price book for 1917, the one-hundredth edition. It is published at the price of 4*s.* by Kelly's Directories, Limited, 182 to 184, High Holborn, W.C. It is stated to contain about 73,000 prices. These cover the whole of the trades connected with building, and, besides the prices, interesting data are given as to strength of materials, their weight, &c. Reference to all the items is facilitated by a very complete index. A most valuable feature of the present edition is an alphabetical list of over thirty closely printed pages of specialities, wherein we find, for example, that the "Electroil" lift is manufactured by Messrs. Waygood-Otis, Limited, Falmouth-road, Great Dover-street, S.E.; that "Mirolux" trough reflectors can be obtained from the British Thomson-Houston Company, Limited, 77, Upper Thames-street, E.C., and so forth. The book also gives the Acts of Parliament and the London County Council By-Laws, &c., connected with the building trades.

What the War is Costing Germany.—According to *The Marine Journal*, New York, it is estimated that the war is costng Germany about 21,000,000 dols. a day, and that the total cost to December 31, 1916, has been about 14,600,000,000 dols. The borrowings from the beginning of the war to December 31, 1916, have totalled some 11,510,000,000 dols. As to future taxes, it is estimated that if the war ended by April 1 of this year Germany would require, at her present rate of expenditure, an annual revenue of 3,250,000,000 dols. The total taxable income of Germany is estimated at 9,750,000,000 dols. If the whole revenue needed were to be raised by direct taxation, this would be equal to one-third of the total national income, so that a family earning 15 dols. a week, or 750 dols. a year, would have to set aside annually 250 dols. for taxes. This is, of course, impossible, adds our contemporary, even with a graduated tax, and it appears that the only course will be indirect taxation of extraordinary proportions.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal and Scotch Pig-Iron Warrant Markets.)



Note.—In the diagrams above the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for antimony and lead are for English metal in both cases, whilst those for spelter are for American metal. The prices are per ton, but in the case of quicksilver, however, the price is per bottle; the price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7 the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. These quotations are still in force. (For official regulations see page 45, vol. cii.)

Paper as a Raw Material in Germany.—The war has given a fresh impetus to the efforts started prior to the war for using paper as a raw material in several industries. Amongst the new departures, paper yarn seems to promise well, more especially in the jute industry, where paper by many is considered likely to find application also after the war. Further, paper is being used with good results for string, boot-laces, curtain cords, &c. Materials are also made from paper yarn, with good results. To commence with it was used together with other materials, but by degrees it has been used more and more independently. Paper also lends itself to the manufacture of tubes and pipes for numerous purposes, and experiments are being proceeded with. Paper tubes are found suitable for lighting gas, and in withstanding an internal pressure they are reckoned to be from three to four times as strong as lead pipes. Impregnation for carrying water has not so far proved really efficient, but experiments in this direction also are being continued. For carrying oil, paper pipes have proved satisfactory, as the artificial resin with which the pipes are treated shows a strong resistance against the influence of oil. Paper pipes can be made in small dimensions, down to or even below 5 mm. ($\frac{1}{5}$ in.) in diameter. They have also proved very efficient as insulation for electric lines.

METAL MELTING BY MEANS OF HIGH-PRESSURE GAS.*

By C. M. WALTER, B.Sc. (Birmingham).

THE application of town's gas for the melting of brasses, bronzes, and other alloys has during the last few years received considerable attention, and at the present time, in many localities where gas can be obtained for this purpose at a reasonably low rate, it is being largely used in this connection, with considerable economy in melting costs.

Many excellent types of furnaces are now obtainable from the various firms who specialise in this work, and crucible furnaces having pot capacities from 50 lb. to 800 lb. are now commonly met with. Such furnaces may be classified into three distinct groups, according to the manner in which the gas is applied, as follow :—

A. Furnaces designed for working with gas at the ordinary town pressures of 2 in. to 3 in. water-gauge, and fitted with atmospheric burners.

B. Furnaces employing gas at ordinary town pressures with air under a positive pressure of usually 1 lb. to 3 lb. per square inch.

C. Furnaces in which gas is employed at a pressure considerably higher than the ordinary distribution pressures, and fitted with either—(*a*) atmospheric burners, or (*b*) burners designed for working with air under a moderate pressure of about 20 in. water-gauge.

Furnaces under heading A, in which low-pressure gas and atmospheric burners are employed, are used chiefly in connection with the melting of alloys not requiring a higher temperature than 1,100 deg. C., including aluminium alloys, gold alloys and white metals, pots up to 150 lb. (copper) capacity being employed for this purpose.

Under heading B, in which air under a pressure of 1 lb. to 3 lb. per square inch is used, there are the following classes :—

1. Pit furnaces and tilting furnaces used for melting brasses, swarf and scrap, for the production of castings, strip, ingot and billets, the sizes of crucibles varying from 60 lb. to 800 lb. capacity.

2. Furnaces for melting nickel, cupro-nickel and bronze.

3. Furnaces for melting aluminium alloys and precious metals.

Under heading C there are the following classes :—

1. (*a*) Pit furnaces for melting brasses and bronzes for sand-castings, ranging from 60 lb. to 200 lb. capacity.

2. Pit furnaces for melting brasses, bronzes and cupro-nickel, for strip and billet castings, having pots of capacities up to 200 lb.

3. Pit furnaces for melting aluminium alloys, having pots of capacity 200 lb. to 600 lb. (copper).

4. Small furnaces for melting precious metals, having pots of capacity 10 oz. to 200 oz.

* Paper read before the Institute of Metals, Thursday, March 22, 1917.

1. (*b*) Furnaces for melting brasses, bronzes, pure nickel, and for melting non-ferrous metals generally where extremely high temperatures and high speeds of melting are required.

In view of the title of this paper, it is to furnaces belonging to Group C, which will be referred to as high-pressure gas furnaces, that I wish to confine my attention, and although each particular type of furnace has its special advantage to meet a particular requirement, from the results of tests recently carried out it would appear that high-pressure furnaces coming under this heading should be capable of meeting all requirements. In the case of the melting of brass in pots of capacity 60 lb. to 200 lb., furnaces fitted with atmospheric injector burners would be used, but where high speed of melting or extremely high temperatures are required, as in the case of melting of pure nickel, furnaces using high-pressure gas with air under a moderate pressure of about 20 in. water-gauge would be employed.

Dealing first with furnaces employing high-pressure gas with atmospheric burners, the following is a description of a standard design of furnace, having a crucible capacity of 60 lb., and suitable for the melting of brasses and bronzes for sand-casting work.

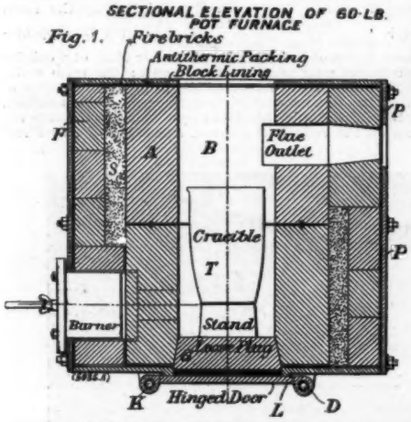
Referring to Fig. 1, which is a sectional elevation of a 60-lb. furnace, it will be seen that the furnace consists of a brick lining A, built up in sections and having a cylindrical core B, of a diameter to suit the particular pot used, the whole of the lining being contained in a box constructed of cast-iron plates P, bolted together loosely so as to allow freedom for expansion and contraction. The outer case is first lined with a 4½-in. wall of firebrick F, leaving a space of about 2 in. between the wall and the lining itself, which is packed with non-conducting material S. The bottom plate forming the bed of the furnace is supported on brick piers in the furnace pit, leaving a free space of about 10 in. between the bottom plate and the floor of pit, so as to facilitate the removal of the circular bottom plate L, which consists of a cast-iron flanged plate, having the same diameter as the lining itself, and being held in place by the hinge at K and the draw-bar D. On the top of this flange plate the furnace bottom G is built, and consists of a mixture of ganister and broken brick, well rammed to a depth of about 3 in., and should it be necessary to remove it for cleaning or removing spilt metal, this can be done in a few minutes by withdrawing the drawbar D, which causes the lid to fall by its own weight, when the bottom can be knocked out from the top with a dumping rod. The pot T rests on a firebrick stand, thus leaving an annular combustion space between the lining and the pot itself. The dimensioning of this combustion space is of the utmost importance if high temperatures and efficient working are to be obtained, and in the case of furnaces where pots are removed by tongs, only sufficient clearance should be given between the outside of pot and furnace lining to allow of easy manipulation of the pot tongs. The high-pressure injector burner enters the combustion space tangentially at a point about ½ in. below the bottom of the pot itself, and the flame forms a spiral round the pot, the waste gases passing away into a brick flue fitted with a damper through a nostril arranged about 2 in. above the rim of the pot itself.

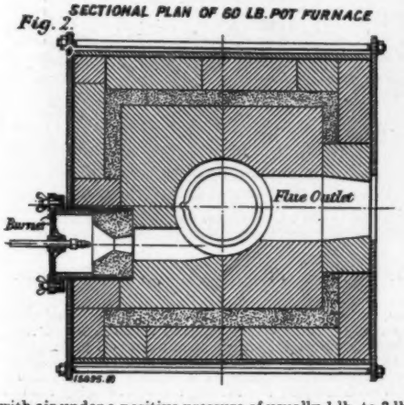
Fig. 2 is a sectional plan.

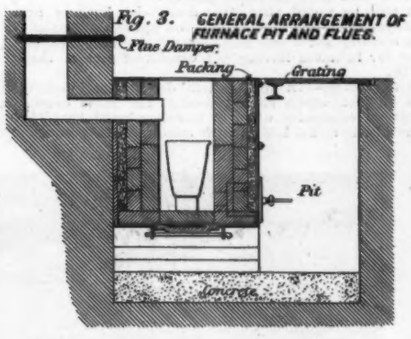
Figs. 3 and 4 represent the general arrangement of furnace, pit and flues.

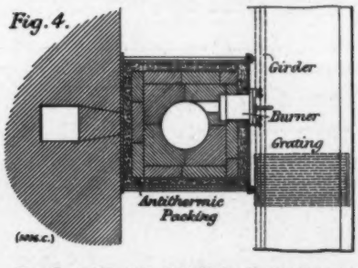
Fig. 5 represents a single high-pressure injector burner, such as would be used on furnaces up to 80 lb. capacity; it consists of a cast-iron thimble carrying a clay injector cone, which fits in a recess moulded in the sectional linings referred to. The burner tubes carrying the jets are supported on cast-iron stirrups, slotted so as to allow the jets to be centred with the injector cones. The jet tubes are adjustable axially with reference to the injector cones, the position of the jet with regard to the injector cone depending on the gas pressure employed.

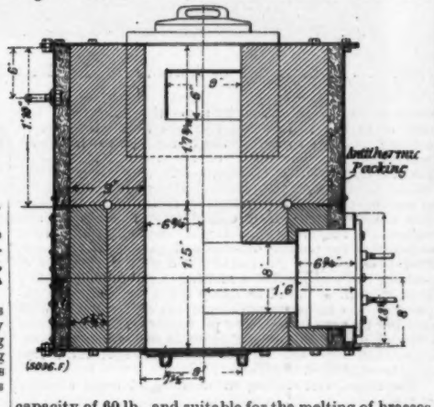
The pressure at which gas is supplied to the jet is usually 11 lb. to 12 lb. per square inch, at which pressure the requisite amount of air for combustion can be injected and a mixture velocity of about 6,000 ft. per minute obtained in the injector throat, the actual velocity of the mixture entering the furnace being about 5,000 ft. per minute. This figure was obtained with a gas of net calorific value of 500 British thermal units per cubic foot (equivalent gross value = 550 British thermal units per cubic foot, which value will be used elsewhere throughout this paper), having a density of 0.52 (air = 1), and requiring 5.5 vols. of air for complete combustion. Taking the density of the mixture as 0.93 (air = 1)











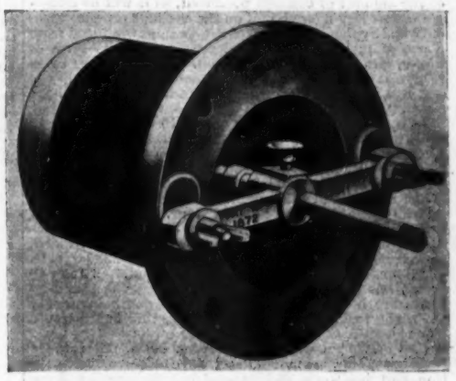


FIG. 5. SINGLE HIGH-PRESSURE INJECTOR BURNER.

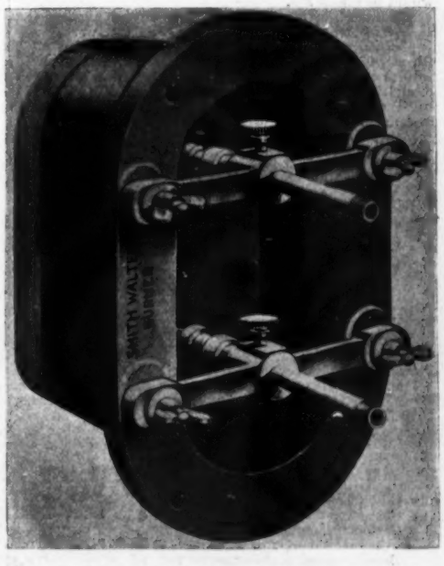


FIG. 6. DUPLEX HIGH-PRESSURE INJECTOR BURNER.

the velocity of the mixture in the throat of the injector cone corresponds to a static pressure of about 2.25 in. water-gauge.

It should be mentioned at this point that, when working with this mixture velocity, the combustion was sufficiently concentrated and flame temperature high enough to meet all the requirements usually met with, temperatures sufficiently high for the melting of cupro-nickel being obtainable; but in cases where extremely high speeds of melting are required, the velocity of the mixture entering the furnace may be increased to as much as 9,000 ft. per minute with advantage: this applying also where very high temperatures are required, as in the case of the melting of pure nickel. The method by which this increased velocity of the mixture may be obtained will be referred to later, and there will now be given details of costs of melting brass in furnaces as described, the figures given having been obtained from large-scale tests carried out in foundries, and these therefore take into account all the stand-by losses which are met with in actual practice.

The figures of fuel cost given are in most cases based on the actual amount of metal melted, quite irrespective of the amount of castings produced, as it will be understood that any figure based on the castings produced will only be of value if the ratio of the castings produced from a pot of metal to the metal returned in the form of ridges, gits and runners is known. In some cases these values have been ascertained by actual weighing up the castings, and returns obtained from a heat of metal are given.

In the case of the melting of 60 : 40 brass in 50-lb. to 60-lb. pots for sand-casting, it is found that with gas having a net calorific value of 500 British thermal units per cubic foot, 9 to 10 heats of metal can be dealt with in a working day of 12 hours, the first heat usually taking about 2 hours, whilst second and subsequent heats should be ready for pouring at intervals of about 1 hour. For a 60-lb. pot furnace fitted with a single injector burner working with a gas pressure of approximately 12 lb. per square inch, the average gas consumption would be about 280 cub. ft. per hour, and the gas per lb. of metal melted (60 : 40 brass) about 5 cub. ft. In cases where the stand-by losses are high, owing to the moulds not being ready when the metal is ready for pouring, this figure would be exceeded.

Cost of Furnaces.—The cost of a 60-lb. pot furnace constructed in the manner described, inclusive of excavation and pit work and connections to existing flues, amounts to approximately 25*l.*, this figure not including the cost of the running of the gas-supply pipes, whilst in the case of a similar furnace of 160 lb. capacity the cost would be about 35*l.*

Where two or more such furnaces are installed at the same time, this figure would be slightly reduced.

Maintenance Costs.—The cost of maintaining such furnaces in a condition such as to give efficient working results will depend on the metal melted and the speed of melting employed, the figures given in Tables I and II being those obtained from 60-lb. and 160-lb. furnace installations.

TABLE I.—*Maintenance Cost of 60-lb. High-pressure Gas-heated Brass Melting Furnace as described above, Melting 8 Heats of Metal per Day.*

Average life of furnace lining = 12 months.

	£	s.	d.
Cost of re-lining	3	0	0
Cost of patching-up, re-bottoming each week for 12 months ...	5	0	0
Burner cone replacements for 12 months' working (1 set)	0	5	0
Total cost	8	5	0

Total metal melted = approximately 60 tons.
Maintenance cost per cwt. metal melted = 1.65*d.*

TABLE II.—*Maintenance Cost of 130-lb. High-pressure Gas-heated Brass Melting Furnace as described above, but with Rammed Ganister Inner Lining, Melting 10 Heats per Day.*

Average life of furnace lining = 6 months.

	Cost per Annum. £	s.	d.
Cost of re-lining (½-ton ganister, 1*l.*)	2	0	0
Cost of re-lining (labour, 11*s.* 8*d.*) ...	1	3	4
Cost of patching-up and re-bottoming each week for 12 months ...	5	7	0
Burner cone replacements for 12 months' working (4 sets)	1	0	0
Total cost	9	10	4

Total metal melted = approximately 160 tons.
Maintenance cost per cwt. metal melted = 0.7*d.*

Life of Pots.—The pot costs vary considerably with each installation, according to the conditions of working. In the case of 60-lb. pots it is found from tests extending over a considerable period that a good average working figure may be taken as 30 heats per pot in the case of furnaces used for producing sand-castings, where 8 to 10 heats per day are the maximum number required, but where the speed of working can be increased it is found that the number of heats per pot obtainable can be increased almost in the same proportion, which can be explained from the following observations.

The pot life is largely dependent upon:—

1. Nature of metal melted.
2. The speed of melting.
3. The period between heats during which the pot is allowed to cool.
4. The temperatures which are employed.

Generally speaking, where high temperatures are employed and the speed of melting is high, the pot costs are lower per hundredweight metal melted than when the reverse is the case, this being undoubtedly due to:—

(i) The higher temperature produces on the outside surface of the pot a protective glaze.

(ii) The temperature changes of the material of which the pot is composed are reduced to a minimum when speed of working is a maximum.

In the case of the melting of borings or swarf, where the metal requires a large amount of puddling, the pot life is considerably reduced, owing to the mechanical wear on the pot which takes place. Where the speed of melting can be increased from 8 to 12 heats per day, it is found in some cases that the life of the pot can be increased to about 40 heats.

In the case of strip and billet casting in pots of 130 lb. to 200 lb. capacity melting 10 heats per day, the average life of a pot is found to be about 26 heats, this figure being slightly higher in the case of the smaller pots, and slightly lower in the case of the larger pots.

Fig. 7 is a sectional elevation of a 160-lb. furnace built up in a cylindrical wrought-iron case, and so arranged that the bottom half-section of the lining can be replaced without disturbing the upper portion.

It will be noted that two double-jet burners are employed, entering the combustion space tangentially from opposite sides, this being the usual burner arrangement for furnaces having pot capacities greater than 100 lb.

Metal Losses.—The loss of metal during metal melting is a subject which should receive the most careful attention, especially when it is remembered that the value of the metal lost in such operations amounts, in some cases, to considerably more than the total fuel cost of melting. It often happens that whilst every attempt is made to reduce the latter cost to the lowest possible figure, the effect of the various systems of heating employed on the former figure are overlooked. In comparing, therefore, the relative melting efficiencies of various types of furnace plant, this question of metal loss should receive full consideration. It is in this connection that very considerable economies have been obtained in the melting of brass with gas-heated furnaces, and if the value of the metal lost during the process of melting be considered as a melting cost, which in reality it is, it will be found in many cases that where high-pressure gas furnaces are employed, as compared with melting by coke in ordinary pit furnaces, the economies effected, owing to the reduction in metal losses alone, more than outweigh the extra fuel cost involved; this may be explained as follows.

The metal lost during the melting of brass consists of:—

1. Spelter which has been volatilised and carried off with the waste gases.
2. Metal which has been oxidised to form a dross.
3. Metal which is spilt over the sides of pot.

The losses under (1) and (2), so far as the brassfounder is concerned, may be considered as non-recoverable, and under (3) as partially recoverable.

In order to reduce these losses to a minimum, in the first place the regulation of the temperature should be under complete control, so as to prevent overheating of the metal and the consequent loss of spelter; secondly, the atmosphere in contact with the surface of the metal should be non-oxidising, and if possible slightly reducing in order to prevent the formation of dross; thirdly, the design of the furnace itself should be such that any metal spilt over the sides of the pot is easily recoverable.

The desiderata referred to above can be obtained only to a limited degree in the case of the coke-heated furnace by reason of its design and principle of working; but, as will be easily understood, in the case of the gas-heated furnace these requirements are easily obtainable, the regulation of temperature being under complete control, the atmosphere in contact with the surface of the metal being non-oxidising, whilst any metal spilt over the side of the pot is directly recoverable by the removal of the bottom plate from the furnace. Mention should be made, however, at this point that in order to obtain the best results the bottom of the furnace should be taken out periodically for the removal of spilt metal. Dampers should be fitted to all take-off flues, and the regulation of these should be such that the waste gases leave the furnace under a slight pressure, in order to ensure a reducing atmosphere on the surface of the metal in the pot.

Coming to the actual metal loss, it is usual for these figures to be given in pounds of metal per hundredweight of castings produced, and although such figures signify all that is required for a particular class of work, nevertheless, for purposes of comparison, they are of little value, as they do not constitute any basis on which the loss per hundredweight of metal melted can be computed.

For comparative purposes it has therefore been found desirable to take as a basis the figure of loss of metal on the actual metal melted for a given process, assuming that the whole of this metal, less the loss obtained, is converted into castings, billets, or strip as the case may be, which figure, when multiplied by the ratio $\left(1+\frac{\text{weight of returns}}{\text{weight of castings produced}}\right)$, gives the approximate figure of loss for any particular class of work for which the ratio mentioned is known: the ratio really representing the number of times a given quantity of metal has to be re-melted to convert same into castings.

It will be noted that this approximation assumes the loss on the re-melted returns, consisting of ridges and gits, to be the same as in the case of the original metal from which they were produced, which is found to be sufficiently near for all practical purposes.

FIG. 8. INSTALLATION OF TWELVE 160-LB. HIGH-PRESSURE GAS FURNACES FOR BILLET CASTINGS.

In Table III are given values of metal losses obtained for different classes of work when melting by means of high-pressure gas, the ratio given above being referred to as R.

TABLE III.—*Figures of Metal Loss obtained when Melting with High-pressure Gas Furnaces.*

1. Metal Melted.	2. Work Produced.	3. $R = 1 + \frac{\text{wt. of returns}}{\text{wt. of Castings Produced.}}$	4. Loss per cent. on Metal Melted.	5. Loss per cent. on Work Produced.	6. Capacity of Furnace used in Pounds.
$\frac{62}{38}$ brass	Very light cored castings ..	2.0	2.05	4.1	60
$\frac{60}{40}$ brass	Medium cored castings ..	1.5	2.20	3.3	60
$\frac{60}{40}$ brass	,, ,,	1.6	2.18	3.5	60
$\frac{60}{40}$ brass	Billets ..	1.18	1.52	1.8	130
$\frac{72}{28}$ brass	Strip	1.05	0.59	0.56	160

The percentage loss figures given in column 5 are those actually obtained from tests, and represent the loss of metal on the castings, &c., produced, whilst the figures given in column 4 represent the loss of metal on the metal required to be melted to produce these castings, as computed from the ratio factors given.

Comparing these losses with those which obtain when melting by coke, figures obtained from various installations of 60-lb. coke-heated pit furnaces show that in the case of the melting of 60 : 40 brass for sand-castings the losses usually amount to 6 lb. to 7 lb. per hundredweight

of castings produced, as compared with 3 lb. to 4 lb. in the case of gas. In taking into account the saving effected by a reduction in the metal losses, it should be remembered that any metal saved appears as castings, strip, or billet, as the case may be, and its value in this condition must be that which is taken into account.

TABLE IV.—*Record of a Test on Twelve 50-lb. High-pressure Gas Brass Melting Furnaces.*

Foundry test on twelve 50-lb. brass melting furnaces. (High-pressure gas.)

		Cub. ft.
Meter at commencement	...	... 11,371,700
,, finish	... ...	... 11,400,200
		lb.
Weight of metal per heat	...	... 50

TABLE V.—*Summary of Results of Tests on Melting Cupro-nickel in a 130-lb. High-pressure Gas-heated Furnace.*

Summary of Tests on Cupro-nickel Melting.

Furnace was a 130-lb. crucible furnace.
Gas calculated at 1*s.* 3*d.* per 1,000 cub. ft.
Consumption, 495 cub. ft. per hour.

Average gas consumption per 84 lb. melted	792 cub. ft.
Average gas consumption per 112 lb. melted	1,057 ,,
Average gas cost per cwt. melted	15.8*d.*
Average gas cost per ton melted	1*l.* 6*s.* 3½*d.*
Average gas consumption per lb. melted	9.4 cub. ft.

Table V gives a summary of the results of tests carried out in connection with the melting of 80 : 20 cupro-nickel in a 130-lb. high-pressure gas-heated pit furnace, during which thirteen 84-lb. heats of metal were melted, the average gas rate per hour being 495 cub. ft., and the average gas consumption per heat being 792 cub. ft., corresponding to 9.4 cub. ft. per lb. of metal melted.

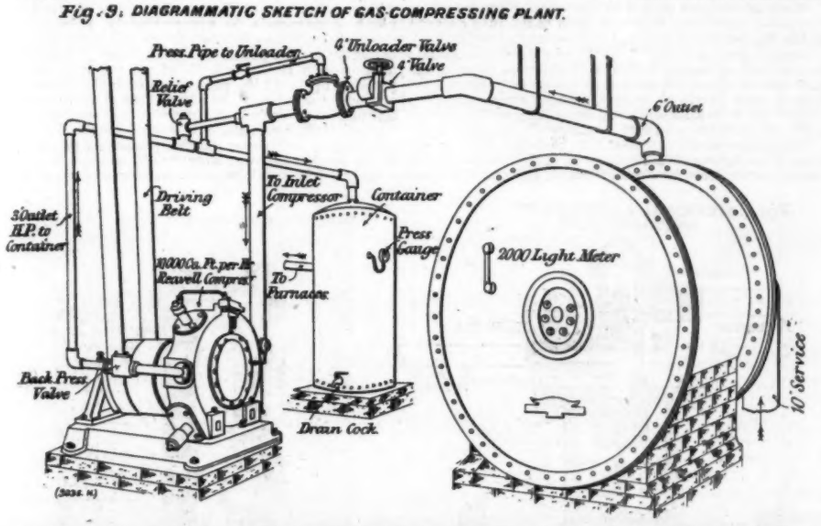
Table VI gives the results obtained from tests carried out in connection with the melting of 72 : 28 cartridge metal. The total metal weighed-in consisted of 75 heats, each of 160 lb., with 66 lb. extra scrap, the charge consisting of ingot copper, spelter and scrap. The heats were made up to 168 lb. in each case by the addition of extra scrap and clean spillings from the previous heat, with the result that the total quantity of metal actually melted amounted to 12,600 lb. The average consumption of gas per heat of 168 lb. amounted to 1,042 cub. ft., which is equivalent to 6.2 cub. ft. of gas per lb. of metal melted. The average loss amounted to 0.59 per cent.

Fig. 8 is a photograph of a battery of twelve 130-lb. high-pressure gas-heated pit furnaces used in connection with the melting of brass for the production of 100-lb. billets. In this installation the gas is taken from the main at ordinary town pressure, and compressed up to a pressure of 12 lb. per square inch on the premises.

Fig. 9 is a diagrammatic sketch of the compressing plant used for this purpose, and will be referred to later.

Table VII is a summary of the results obtained with the melting plant referred to taken over 12 months' working.

Fig. 9. DIAGRAMMATIC SKETCH OF GAS-COMPRESSING PLANT.



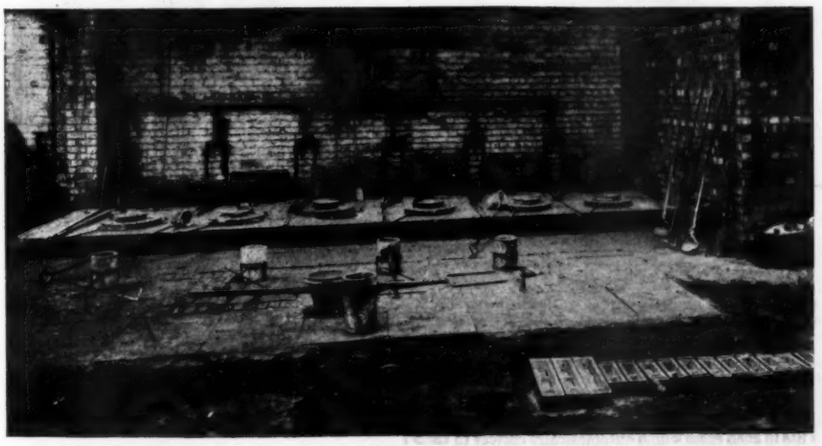


FIG. 10. BATTERY OF SIX 600-LB. (COPPER CAPACITY) ALUMINIUM MELTING FURNACES.

Summary.

Total number of heats (12 furnaces)	75
Total weight of metal melted (average 50 lb. per heat) (1 ton 13 cwt. 1 qr. 26 lb.)	lb. 3,750
Total gas consumption for the day...	28,520 cub. ft.
Average gas consumption per heat...	380 ,,
,, ,, ,, cwt....	851 ,,
,, ,, ,, lb. of metal melted	7.6 ,,

Table IV is a summary of the results of a day's test carried out in a foundry where twelve 50-lb. pot furnaces are employed for the production of light and medium-cored work. Although the figures of melting cost are considerably higher than would have been the case had the furnaces been working up to their maximum melting capacity, nevertheless the conditions of working are representative of what might be expected in an ordinary foundry, where, owing to the nature and variety of the work dealt with, the stand-by losses must be necessarily higher than in the case of repetition work, where moulding machines would be employed. Full details of this test have been lodged with the secretary for inspection.

The plant referred to had been working daily for 12 months prior to the tests being made and, with the exception of one furnace, no linings had been replaced. Further, other tests carried out showed that a figure of gas consumption of 4.5 cub. ft. per lb. of metal melted could be obtained when the furnaces were melting up to their full capacity.

TABLE VI.—*Record of Test on Melting of 72 : 28 Cartridge Metal in 160-lb. High-pressure Gas Furnaces.*

No. of Heats	Consumption of Gas in Cubic Feet.	Weight of Metal.	Cost of Melting per Cwt.	Consumption of Gas per Hour.	Length of Day.
		lb.	*d.*	C. ft. Over.	hr. min.
4	4,670	672	11.6	557 ,,	8 23
5	5,400	840	10.8	666 ,,	8 6
5	5,000	840	10.0	689 ,,	7 15
6	5,900	1,008	9.8	690 ,,	8 33
6	5,600	1,008	9.3	660 ,,	8 29
5	5,700	840	11.4	712 ,,	8 0
6	5,900	1,008	9.8	695 ,,	8 43
6	6,150	1,008	10.2	696 ,,	8 50
6	6,190	1,008	10.3	687 ,,	9 0
6	6,089	1,008	10.1	688 ,,	8 54
5	4,950	840	9.9	571 ,,	8 40
5	5,800	84	11.6	696 ,,	8 20
6	6,000	1,008	10.0	666 ,,	9 0
4	4,830	672	12.2	703 ,,	6 52
75	78,179 (Total)	12,600 (Total)	10.5 (Average)	669 ,, (Average)	— —

Five pots were used. Heats from each :

No. 1 (old pot)	4
No. 2 (new pot)	10
No. 3 ,,	17
No. 4 ,,	21
No. 5 ,,	24
Average consumption of gas per heat (168 lb.)	1,042 cub. ft.
Average consumption of gas per hour	670 ,,
Average cost of melting per cwt.	10.52*d.*

Losses :	cwt.	qr.	lb.
Total metal produced	106	1	9
Returns, *i.e.*, spillings	0	1	19
Losses	0	2	15½
Meta recovered from bottom of furnace	0	1	10½
Total metal melted, *i.e.*, included in heats	107	2	26

Percentage loss ... ... 0.59 per cent.
Average gas consumption per lb. metal melted ... ... 6.2 cub. ft.

Metal sent in :	lb.
75 heats, 160 lb. each	12,000
Extra scrap	66
	12,066

TABLE VII.—*Summary of Results of 12 Months' Working with Twelve 160-lb. Furnaces for Billet Work.*

No. of furnaces installed	12
No. of furnaces used at one time	8
Capacity of pots ...	130 lb.
Meter reading—	
December 29, 1916 ...	14,768,900
January 21, 1916 ...	426,400
Total gas used ...	14,342,500
Total metal melted ...	1,086 tons
,, ,, ,, ...	2,432,640 lb.
Gas used per lb. metal melted...	14,342,500 = 5.9 cub. ft.
	2,432,640

Average life of pots = 28 heats of 110 lb.

Maintenance Costs per Furnace per Annum.

	£	*s.*	*d.*
Cost of fettling and re-bottoming	5	7	0
Cost of re-lining with rammed ganister twice per year :	£	*s.*	*d.*
1-ton ganister	2	0	0
Labour	1	3	4
	3	3	4
Burner cone replacements (4 sets) at 5*s.* per set... ...	1	0	0
Total maintenance cost	9	10	4

Total metal melted per furnace per annum = approximately 160 tons.
Maintenance of cost per cwt. metal melted = 0.7*d.*

TABLE VIII.—*Summary of Results of 12 Months' Working with two 60-lb. and one 160-lb. High-pressure Gas Furnaces.*

Two furnaces used :
One 60-lb. pit furnace for sand-casting.
One 160-lb. furnace for metal mixing and running down scrap.
Metal melted = 62 : 38 brass.

	lb.
Total finished castings produced ...	58,683
Ingot metal produced from scrap and new metal	32,595
Total ingot and castings produced	91,278

Ratio factor: $1 + \frac{\text{weight of returns}}{\text{weight of castings produced}} = 1.55$

Total gas used	1,103,210 cub. ft.
Gas per lb. of castings produced	12.00 ,,
Average pot life	30 heats
Average loss of metal on castings produced	4.1 per cent.
Average loss of metal on metal melted	2.6 ,,
Total maintenance cost of linings (3 furnaces) ...	12*l.* 13*s.* 7*d.*

Table VIII is a summary of the results obtained in the case of a small plant consisting of two 60-lb. high-pressure gas pot furnaces for sand-casting, and one

160-lb. furnace for metal mixing and scrap melting, the gas in this case being compressed on the premises; and owing to the whole of the gas for both the large and small furnaces being registered by one meter, it is impossible to give a dissection of the amount of gas used for each particular process.

The results of a large number of tests show that, in the case of the melting of brass of approximate composition 60:40 in high-pressure gas furnaces, the gas consumption, allowing for all stand-by losses, amounts to approximately 6 cub. ft. per lb. of metal melted in the case of ingot, strip and billet work, the metal loss in this case being about 1.8 per cent. of the metal melted; and to 12 cub. ft. per lb. of castings produced in the case of medium and light cored castings, the loss in this case amounting to about 4 per cent. of the metal melted.

TABLE IX.—*Comparative Furnace Costs of Melting 60 : 40 Brass in Coke and High-pressure Gas Furnaces in 60-lb. Pots for Sand-castings.*

Costs per Cwt. Castings produced (R. = 2).

With High-pressure Gas of Calorific Value = 500 British thermal units net,* at 1s. 6d. per 1,000 cub. ft.		With Coke at 25s. per ton.	
Fuel cost.	d.		d.
Taking 12 cub. ft. gas per lb. castings produced	24.0	Taking 1 cwt. of coke per cwt. castings produced	15.0
Pot cost.			
Taking life as 30 heats per pot	8.0	Taking life as 30 heats per pot	8.0
Maintenance and repairs.			
Re-bottoming each week and re-lining once each year	1.65	Fettling each week, and re-building once each year	2.04
Interest on capital outlay.			
At 5 per cent per annum, taking cost 25l. per furnace	0.50	At 5 per cent. per annum, taking cost 10l. per furnace	0.20
Depreciation.			
Taking life as being 10 years	1.00	Taking life as being 10 years	0.40
Value of metal loss.			
Taking this as being 4 lb. and equal to value of castings at, say, 10d. per lb.	40.00	Taking this as 6lb. at 10d. per lb.	60.00
		Cartage of ashes ..	0.50
Total costs	75.15	Total costs	86.14

NOTE.—From the above it will be seen that with gas at 1s. 10d. per 1,000 cub. ft. and coke at 15s. 6d. per ton delivered, the furnace costs would be about equal.

* Equivalent to approximately 550 British thermal units (gross).

Table IX gives the comparative costs of melting brass by high-pressure gas and coke for the production of medium sand-castings, where the weight of castings produced is approximately equal to the weight of the returns (ridges and gits), the costs given being the cost per hundredweight of castings produced in each case.

Melting of Aluminium in High-pressure Gas Furnaces.—An equally important application of the use of high-pressure gas is in connection with the melting of aluminium and aluminium alloys, and for the production of fine-quality castings and high tensile alloys of this metal, owing to the cleanliness, convenience and ease of temperature control, the high-pressure gas furnace may be said to have firmly established itself in this connection on the score of both efficiency and economy. For the melting of such alloys on a large scale the furnace usually employed is one constructed on similar lines to those already described, heated by means of high-pressure injector burners, with gas at a working pressure of about 12 lb. per square inch. These furnaces are usually built to take pots of capacity 500 lb. to 600 lb. (copper), the metal being ladled from the melting-pots into smaller pots for carrying to the moulds. With such plant it is found that, in the case of the melting of the ordinary commercial aluminium alloys, during a working day of 12 hours, 10 heats of metal of about 200 lb. each can be obtained from each furnace, with a gas consumption of 12,000 cub. ft. to 14,000 cub. ft. per ton of metal melted.

Fig. 10 represents a battery of six such furnaces having pot capacities of 600 lb. (copper). When working under the conditions mentioned above the pot life is found to average 25 days' work, with a corresponding pot cost of approximately 1.6*d.* per hundredweight metal melted. The life of the linings in the case of a very large installation, in which over thirty such furnaces have been in continuous use for upwards of five years, approximated to three years' work, allowing for patching-up at the end of each week.

It may be interesting to note that one firm alone, in Birmingham, is taking as much as 25,000 cub. ft. of high-pressure gas per hour, continuously, for melting aluminium alloys, over sixty furnaces being used in this one installation.

General Notes.—In all the plant referred to above the figures of gas consumption and cost of melting are based on the gas used having a net calorific value of 500 British thermal units per cubic foot† and being supplied at a working pressure of 10 lb. to 12 lb. per square inch, this pressure being found to be necessary where injector burners are employed if high efficiencies are to be obtained. The advantages to be derived from the use of the injector burner will be at once apparent when it is remembered that such a burner is to a great extent automatic in its action of providing the necessary air for the complete combustion of the gas used over a wide range of gas consumption, and at the same time is self-compensating for slight variations which may take place in the gas supply pressure, the amount of air injected being proportionally greater or less according as the pressure rises or falls within such limits as would be ordinarily met with. Further, the simplicity of control by one tap eliminates errors which are likely to occur where both air and gas are used, the latter system necessitating readjustment of the mixture from time to time if efficient results are to be obtained.

Many advantages gained by the use of gas as a fuel, as compared with coke, have not been taken into account in the figures of cost given above, owing to the difficulty of assigning a correct value for the advantages so gained; but as such advantages, due to cleanliness, convenience and ease of manipulation, must necessarily reduce the labour costs involved in any melting operation, they should not be overlooked when comparing such a system with one in which solid fuel is employed.

Gas-compressing Plant.—It will be noted that, in the case of the figures of fuel cost given in the various tables above, no mention has been made of the costs of compressing the gas used, owing to, in the majority of the cases referred to, the gas being supplied direct from a high-pressure gas main at the full working pressure.

In Birmingham some 24 miles of mains carrying gas at a pressure of about 12 lb. per square inch form part of the distributory system, and in cases where manufacturers have their premises situated on the line of route of these mains they are able to obtain a supply of gas at this pressure, special meters having been designed for use in such cases which automatically correct in their registering the actual volume of gas used under the particular working pressure to the equivalent volume of gas if measured at ordinary town pressures. Where, however, consumers requiring high-pressure gas are not in a position to obtain such a supply direct from the main, it becomes necessary for gas-compressing plant to be installed on the consumers' premises, and in such cases the type of plant used will depend upon the pressure which is required. If the pressure required does not exceed 5 lb. per square inch, rotary type machines can be used; but in the case of higher pressures compressors of the reciprocating type must be employed.

Referring to Fig. 9, which represents diagrammatically the general arrangement of a compressing plant capable of dealing with 10,000 cub. ft. of free gas per hour, and delivering same at a pressure of about 12 lb. per square inch, it will be noted that the low-pressure supply to the meter passes through a 10-in. pipe, whilst after compression a 3-in. pipe is sufficient to convey the same volume of gas to the point of combustion. The gas entering the inlet of the compressor is controlled by means of an apparatus known as an unloader, which is fixed to the inlet side of the machine, and consists of a piston-operated valve controlled by the working pressure on the outlet of the machine, and so arranged that the amount of gas admitted to the compressor corresponds with that used on the outlet, so that the power taken to drive the compressor is approximately proportional to the amount of gas used, and, moreover, a constant supply pressure on the outlet of the machine is maintained.

Fig. 11 gives details of the construction of such a valve designed by the author to meet this requirement.

The author would specially emphasise the importance of employing such a system of control in favour of the usual form of by-pass valve, where the gas which is not used on the outlet of the machine is by-passed back on to the inlet; in which case the machine is running at full load the whole of its time, and is taking the most power to drive it when delivering the least quantity of gas.

The saving of power effected by the employment of an unloader has in some instances amounted to many thousands of horse-power hours per year, whilst at the same time the wear and tear on the compressor itself is reduced to a minimum.

Costs of Compressing Gas.—It is found that for each pound of gas compressed and delivered at a gauge pressure of 12 lb. per square inch an expenditure of energy amounting to about 36,500 ft.-lb. is required, which, allowing for the inefficiencies of compressing plant, corresponds to approximately 1 brake horse-power hour for each 1,000 ft. of gas compressed and delivered at this pressure. In the case of a compressor dealing with 10,000 cub. ft. of gas per hour and compressing up to 12 lb. per square inch the cost of compressing plant would be about 300*l.*,* and the cost of compressing, including interest on capital outlay, depreciation, renewals, oil, waste, stores, labour and attendance, and power charges (assuming power to cost 0.75*d.* per horse-power hour) would amount to approximately 1.75*d.* per 1,000 cub. ft. of gas compressed and delivered, the total gas dealt with amounting in this case to approximately 22,500,000 cub. ft. per annum.

Combined High-pressure Gas and Air Systems.—In cases where the high-pressure gas injector burner will not fulfil such conditions as may be required for processes such as the melting of pure nickel, where extremely high temperatures are necessary, or in the case of the melting of swarf or scrap in pots of large capacity with a maximum speed of melting, recent experimental work has shown that with a combination of gas at a working pressure of about 4 lb. per square inch and air at a pressure of about 20-in. water-gauge (as might be obtained from a high-pressure fan) excellent results may be obtained with suitably-designed burners. In this case a double injector burner is employed, the mixture being injected into a mixing chamber prior to passing into the burner tube, and with efficient mixing, by employing air and gas at the pressures mentioned, a mixture velocity of about 10,000 ft. per minute can be obtained in the burner tube. I might mention, however, that when working with these high velocities the life of the lining is considerably shortened and the furnace maintenance costs increased.

Fig. 12 represents a burner designed primarily for use with low-pressure gas and air, under a pressure of about 2 lb. per square inch, but which can be modified by the attachment of another injector for use with both gas and air under pressure, as referred to above.

Before concluding this paper, the author desires to make mention of another advantage to be gained by employing gas at moderate pressures of about 4 lb.

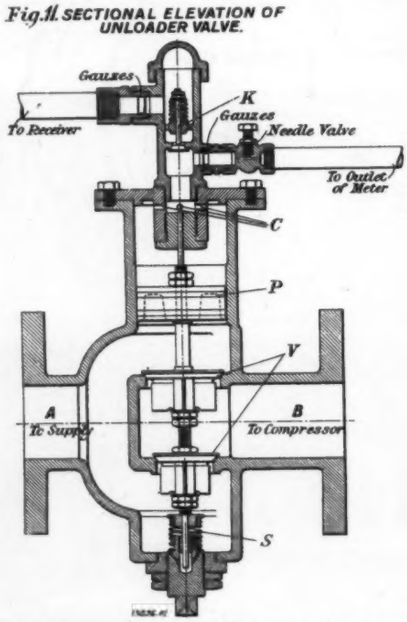


Fig. 11. SECTIONAL ELEVATION OF UNLOADER VALVE.

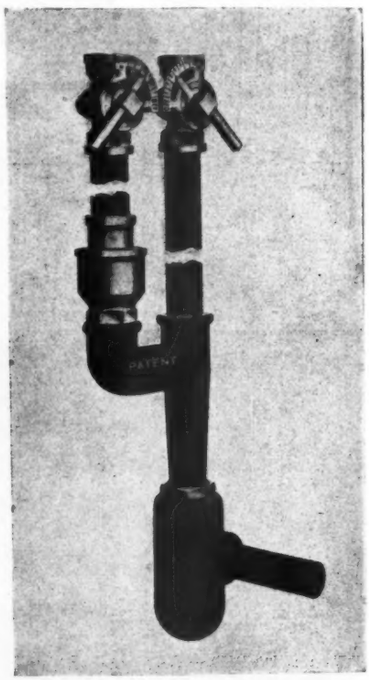
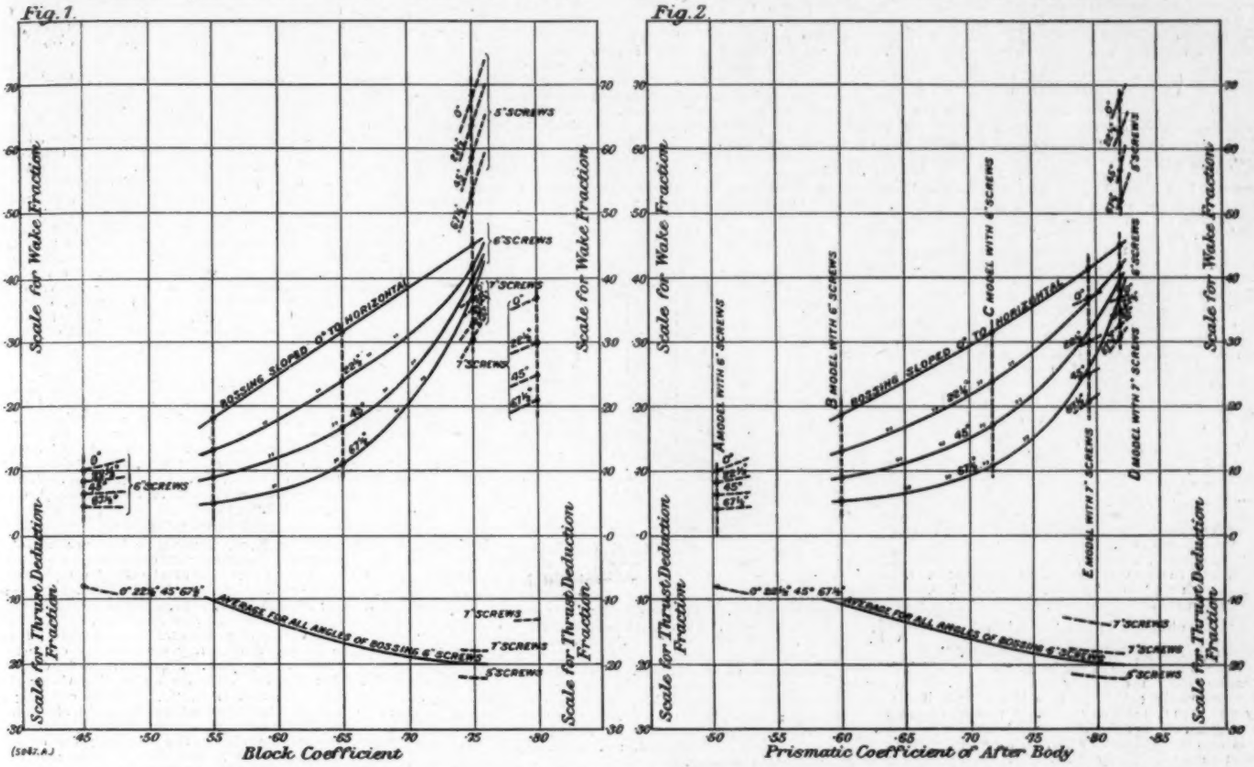


FIG. 12. BURNER DESIGNED FOR LOW-PRESSURE GAS AND AIR, OR HIGH-PRESSURE GAS AND AIR UNDER PRESSURE.

† Equivalent gross value = 550 British thermal units per cubic foot.

* Pre-war prices.

EXPERIMENTS ON WAKE AND THRUST DEDUCTION PROBLEMS.



per square inch, instead of at the ordinary pressure of about 3-in. water-gauge, in connection with heating plant fitted with burners designed for use with air at a pressure of about 2 lb. per square inch and gas at ordinary pressures, owing to the relatively small variation in the quantity of gas consumed which takes place for a given variation in the supply pressure when the supply pressure is high, as compared with that which takes place when the supply pressure only amounts to about 3-in. water-gauge. Taking as an example the variations in the quantity of gas consumed, with a given adjustment, which would take place for a pressure variation of, say, $\frac{1}{16}$-in. water-gauge, with working pressures of 3-in. water-gauge and 4 lb. per square inch respectively, these would amount to about 8.5 per cent. in the former case, as compared with about 0.2 per cent. in the latter case. It is not infrequent that pressure variations of $\frac{1}{16}$-in. water-gauge are met with, especially in establishments in which the loads on the gas supply systems vary considerably from time to time, and as it is not always practicable to govern gas pressures at each point of supply, the application of the combined system of gas and air with each under a positive controllable pressure should be a subject to receive more attention.

In conclusion, the writer begs to acknowledge his indebtedness to the City of Birmingham Gas Committee for their permission to read this paper; to his assistants for the help they have given in its preparation; and to the various firms employing high-pressure gas furnaces who have been good enough to supply the various data.

FURTHER EXPERIMENTS UPON WAKE AND THRUST DEDUCTION.*

By MR. W. J. LUKE.

IT has been the pleasing duty of the writer to present to the Institution two papers on this subject, one in 1910,† followed by another in 1914.‡ The first of these contributions dealt with the results of experiments on one particular model, chosen so as to represent, as nearly as could be judged, a mean of current practice; the principal feature of that paper was the section dealing with the variations in value of the hull efficiency elements due to variations in angle bossing. It may be recalled that with twin outward turning screws the adoption of horizontal bossing led to large wake fractions, and that considerable diminution of these wakes resulted from sloping the bossing; the reverse result was reached with inward turning screws. The effect of these variations on the thrust deduction fraction was much less marked. Other results were reported, but were of a distinctly less novel character. The contribution made in 1914 extended these results of the cases of quadruple screws, and also gave results to experiments with screws centrally placed.

It was quite evident that much ground remained to be covered by experiment; for example, changes in proportion of the ship's dimensions might have a perceptible effect on the values of the factors under discussion, but it seemed from the examination of a number of isolated examples that no great variations would probably be found to result. It was known that this was not the case with variations in fullness of form, consequently the present notes have been compiled as complementary to the previous contributions and may perhaps be looked upon as finishing the present writer's contribution to this subject.

As it was expected that the variations in wake values would be tolerably regular, the experiments were first planned for two models, one with a block coefficient of 0.55, and the other of 0.75. They were of the same linear dimensions as the model of 1910, viz.:—

	in.
Length	204
Beam	30
Draught	9

This seemed to promise with that model such a series as would—with a little extrapolation—cover all usual cases. There appeared to be no necessity to multiply experiment, nothing was done with inward turning screws, and it was at first intended to make no variations in propeller dimensions. The 6-in. propellers of the original experiments were made use of, placed just as before, viz.: with a spread between their axes of 10 in. with their centres 1½ in. before the after perpendicular, and with 2 in. immersion. Bossings were fitted at four different angles of inclination, viz.: at 0 deg., 22½ deg., 45 deg. and 67½ deg. from the horizontal, and were uniformly ¾ in. thick, rounded on the outer edge and well tapered abaft. In all these details it will be seen that the original data have been entirely followed.

No records of rotative efficiency were taken, as the actual screw efficiency has no especial bearing on these investigations.

Standard speeds of $\frac{V}{\sqrt{L}} = 1.00$ and $\frac{V}{\sqrt{L}} = 0.66$ were adopted for the two models respectively. The curves shown in Fig. 1 represent the results of the experiments associated with those previously presented for the model of 0.65 block coefficient, and show that while the results of the finer of the two new models were just about what might have been expected, those for the fuller model were higher than looked for, and showed very moderate variations, due to variations in angle of bossing; in this latter case the experiments were repeated in their entirety and their substantial accuracy was confirmed.

As previous experiments had led to the expectation that the plot of wake values on a basis of fullness would have assumed an approximately rectilinear form, the result was nothing short of disappointing. However, after considering a number of possible reasons for this result, it was at last concluded that although not much influence might have been exerted by the selected relations of length to transverse dimensions, yet for a model of the fullness adopted the relation of width to depth was abnormal, and as a partial result of this the screw was on the small side. Sets of experiments with screws of 5 in. and 7 in. in diameter were made and thoroughly confirmed this latter conclusion.

To complete, it was therefore decided to make experiments on another model with a proportion of draught to breadth of 0.475 and with 7.5 beams in the length. The departure from the previous $\frac{\text{Length}}{\text{Breadth}}$ proportion was made somewhat reluctantly, but upon consideration that the results would probably be but little affected thereby, and as there was a pressing reason for time economy when the experiments were made, this variation from precedent was accepted.

The draught of the new full model thus became 12.9 in.; and in the experiments screws of 7-in. diameter were adopted, with a tip immersion of 4 in. The results of these experiments were fairly harmonious with preconceived ideas; and serve to show (with full ships at least) what wide variations may result from unsuspected causes.

Opportunity also offered to run a few experiments with a model of as low a block coefficient as 0.45; here, again, the proportions are not quite those adopted as standard. The speed adopted was $\frac{V}{\sqrt{L}} = 1.33$, and the results are shown for comparison.

It is of great importance here to note that these values will not apply to vessels of excessively high speed in relation to size; although as regards fullness of form they come within the range dealt with in this communication. Torpedo-boat destroyers and other light craft, whose speeds are pushed up to values of $\frac{V}{\sqrt{L}} = 2$ and beyond, seem to have reached an order of circumstance different in character. Taylor has pointed out that increase in fullness for the same length and displacement gives rise to diminution in resistance, and analysis at least shows that the wake has a negative value. It must, therefore, be carefully borne in mind that the results here presented are not applicable to vessels of this type.

So far, only wake has been mentioned, as it is that factor of the hull efficiency which seems to be subject to the greatest amount of variation. It will suffice to note merely that the thrust deduction values are exhibited in the companion curve, and really call for no special remark.

It may be asked—what is the purpose of all this investigation? The answer is, that it is an essential to assess fairly the elements of a propeller in the stage of design, and is by no means for the purpose of showing where a propeller is to be placed so as to get the "maximum return from the wake current." For the

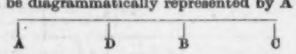
*Paper read at the Institution of Naval Architects, March 29, 1917.

† Trans. I.N.A. vol. liii, page 43. ENGINEERING, vol. lxxxix, pages 374, 392.

‡ *Ibid.* vol. lvi, page 33. ENGINEERING, vol. xcvii, pages 452, 462.

purpose of making this clear, it will be well to repeat a paragraph from the communication of 1910. The method of experiment and the subject of experiment were thus described—

"It may be imagined that a travelling carriage can be made to run over a body of water, and at a speed that can be diagrammatically represented by A B.



"Imagine next that this carriage carries a screw propeller made to revolve at such revolutions that if working without slip its speed of advance would be A C. Then B C is the slip, and $\frac{B\,C}{A\,C}$ the slip as ordinarily expressed as a fraction of the propeller speed, or as a percentage by being increased a hundredfold. The conditions under which such a propeller is working are described by the word 'open,' and are not the same as those in which a propeller works when propelling a ship.

"The ship in its onward path is followed by a belt of water of complex motion, and if (over the propeller disc) it can be assumed that its average forward velocity is D B, the propeller is carried along at the former speed over the ground, and, being revolved as before, would behave in some respects as would an 'open' propeller advancing with a speed A D and with a slip D C.

"The wake velocity, as before stated, is D B.

"The wake fraction w is $\frac{D\,B}{A\,D}$, as in Froude's original nomenclature.

"The apparent slip is B C, and the apparent slip ratio $\frac{B\,C}{A\,C}$.

"The real slip is D C, and the real slip ratio $\frac{D\,C}{A\,C}$.

"The thrust is appropriate to the speed of advance A D and a slip D C.

"The thrust, however, is being overcome at a velocity A B, and the apparent work is thrust × A B, instead of, as with an 'open' screw, thrust × A D, and under such circumstances the work 'behind' shows an excess over that obtained in the 'open' in the ratio $\frac{A\,B}{A\,D}$, the excess over unity being the 'wake gain.'"

So that the factor in the hull efficiency which denotes "wake gain" has already been exactly allowed for in a corresponding deduction in the suppositious speed by which the thrust advances. There is in fact no such wake gain, though the idea recurs from time to time.

It was pointed out by Mr. Baker * that wakes might be more satisfactorily dealt with by considering their variations in relation to the prismatic coefficients of the after-body. Fig. 2 shows the results plotted on this base. It is certainly more regular in form than the graph on a base of block coefficient of the whole form, and consequently it might be well, in accumulating data, so follow this line. It calls for no further remark in this connection.

A most important use to which the sum total of the information available on this subject can be put is in its application to the results of trials. A trial carefully conducted results in records being obtained of horse-power, speed, and revolutions of propellers; and probably also some idea of the efficiency of the result achieved; at least whether the result is good, indifferent, or disappointing, even if the resistance of the ship, as derived from model experiments, is not known. These data furnish the only records from the ship and machinery from which an estimate of the various causes contributing to the efficiency of the whole installation can be assessed. One very important feature is the efficiency of the propeller, which in turn is largely bound up with the slip at which it is working; and before the real slip as distinct from apparent slip can be determined, some approximation to the wake must be made.

There is no doubt that when any large collection of data has been got together it must be carefully analysed in order that the information contained in it can be made generally available; failing this, departure in a design from some previous example in any material degree can be nothing more than a leap in the dark.

For the purpose of the analysis here mentioned some scheme of model propeller experimental results is also necessary, and there exists a choice of four or five different sets. These all differ from each other, not fundamentally, it is true, but sufficiently so to suggest that, wherever practicable, one and only one set of curves should be used when a number of different results are being analysed. With them it may also be found that the absolute figures for wake and thrust deduction may not hold just as they have been published; but at least it may be hoped that comparatively the results may be found to be useful to those who are engaged in the pursuits of naval architecture and marine engineering.

The whole comparable data on wake presented in my three papers are collected in Fig. 3, which may fairly well suffice for design purposes. The results of analysis of the speed trials in ten different cases, indiscriminately chosen, will serve to show what variations may exist between experimental data and the probabilities of actual facts.

In conclusion, it must be mentioned that this and previous papers could not have been presented to the Institution without the hearty co-operation and indefatigable work of the staff at the experimental tank of Messrs. John Brown and Co., Limited, Clydebank, to whom my best thanks are due.

Table I.—*Wake and Thrust Deduction. Particulars of Models.*

Model	δ	(M)	(B)	(D)	ϕ_f	ϕ_a	β
A	0.45	7.25	0.967	0.319	0.542	0.504	0.860
B	0.55	6.45	0.968	0.290	0.540	0.600	0.965
C	0.65	6.20	0.910	0.275	0.627	0.719	0.965
D	0.75	5.82	0.873	0.262	0.734	0.820	0.965
E	0.80	5.29	0.705	0.335	0.820	0.796	0.990

Where δ = block coefficient,
ϕ_f = prismatic coefficient—fore body,
ϕ_a = prismatic coefficient—aft body,
β = mid area coefficient,
(M) = $\frac{L}{\Delta^{\frac{1}{3}}} \times 0.3057$ or $\frac{\text{length}}{U}$,
(B) = $\frac{\text{breadth}}{U}$,
(D) = $\frac{\text{draught}}{U}$.

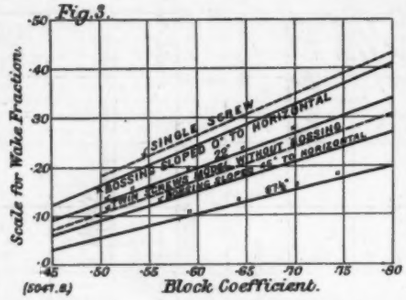
Table II.—*Wake and Thrust Deduction.*

Comparison of Wake Values Obtained by Analysis from Taylor's 1904 (3-*Bladed*) *Propeller Curves and those Obtained from Fig.* 3.

Case.	δ	Angle of Bossing.	Trial Analysis Wake.	From Wake Curves.
		deg.		
Twin-screw cargo ship ..	0.725	25	0.29	0.28
,, yacht ..	0.532	30	0.09	0.14
,, cross-Channel steamer ..	0.481	38	0.10	0.09
,, cruiser ..	0.518	—	0.12	0.12
,, cross-Channel steamer ..	0.498	15	0.16	0.14
,, cruiser ..	0.521	—	0.10	0.12
,, liner ..	0.710	14	0.32	0.30
,, cruiser ..	0.534	—	0.14	0.13
,, cruiser ..	0.510	—	0.07	0.11
,, cross-Channel steamer ..	0.500	20	0.12	0.13

* Trans. I.N.A., vol. lii, page 94.

Fig. 3.



FOREIGN ENGINEERING PROJECTS.

We give below a few data on a foreign engineering project taken from *The Board of Trade Journal*. Further information on this can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Chili.—The *Diario Oficial*, Santiago, publishes a Decree, dated January 6, granting to Don Eugenio Cibié, concessionaire of a tramway system (mechanical traction) between Santiago, Barrancas, El Resbalon and Cerro Navia, permission to construct and work branch lines between Barrancas and Pudahuel and between El Resbalon and the town of Lampa. The gauge of the lines will be 0.75 metre (about 2½ ft.), and the length of the first branch will be about 5½ kilometres (3½ miles), and of the second 22 kilometres (nearly 14 miles). Plans for the construction of the two lines must be submitted for the approval of the Government within periods of six months and two years respectively from the date of the Decree. The Padahuel branch must be commenced within six months from the date of the approval of the plans and be completed within 18 months, while the construction work on the Lampa branch must be commenced within six months and be completed within five years.

British Chamber of Commerce Established at Peking.—Attention is called by *The Board of Trade Gazette* to the recent formation of a British Chamber of Commerce at Peking, having for its objects the promotion and protection of British trade interests in Peking and other parts of China, the settlement by arbitration of disputes, &c. Communications for the Chamber should be addressed to the Secretary, Cultu Chambers, Peking.

Experimental Manufacture of Aeroplanes.—The Minister of Munitions in exercise of the powers conferred upon him by the Defence of the Realm Regulations and all other powers enabling him Orders as follows:—(1) On and after April 1, 1917, no person shall without a licence from the Minister of Munitions commence or proceed with the experimental manufacture of any aeroplane or seaplane or any part thereof other than any kind of aero-engine. Provided that where a first application for a licence under this Order shall have been made and is pending for the carrying on of any experimental manufacture which shall have been commenced before the said April 1, 1917, nothing in this Order shall prohibit the carrying on of such manufacture until the licence shall have been refused. (2) For the purpose of this Order the term experimental manufacture shall mean any manufacture which is not under or for the direct purpose of fulfilling a Government contract, and shall include the preparation of any working drawings but not the preparation of general arrangement drawings. (3) All persons desirous of obtaining licences to commence or carry on any such experimental manufacture as aforesaid shall apply in writing to the Controller of Aeronautical Supplies, Air Board Office, London, W.C. 2, for such licence, and shall give full particulars of the manufacture for which the licence is required, and such further information as the Controller may require, and shall comply with any restrictions or conditions subject to which the grant of such licence may be made.

German Metal for Bearings.—On account of the scarcity of metal in Germany, determined efforts have been made to substitute alloys containing little or no copper for those containing high percentages. It is stated in *Glasers Annalen*, says *Machinery*, New York, that German metallurgists have succeeded in producing a bearing-metal alloy containing a very small percentage of copper and a fairly small proportion of tin, which has all the properties of the highest grade of bearing metal. The alloy consists of 3.3 per cent. of copper, 12 per cent. of lead, 21.3 per cent. of tin and 63.4 per cent. of zinc. The alloy is produced by melting red brass and adding to it first the tin and lead, and finally, the required amount of zinc, which, before being added to the molten alloy, is preheated to about 400 deg. F. The alloy has a hardness of 42 on the Brinell scale.

Dust-Fired Boilers.—The Society of Chemical Industry recently discussed the advantages of dust fuel for boilers in connection with a paper by Mr. C. A. King, M.Sc., on tests made with a Bettington boiler of the Farnley Iron Company (see Journal of the Society, February 15, 1917). The small coal, he said, was pulverised, passed through a sieve of 200 meshes per linear inch, and sent up vertically into the combustion chamber, formed by semicircular firebricks lining the innermost ring of tubes. The ashes were converted into a semi-liquid spray which trickled down from the lining, thus heating the gases once more in their fall, which they would not do with a horizontal furnace arrangement. Some of the large particles of the coal escaped unburnt. During the discussion Mr. B. G. McLellan mentioned that he had tested a Bettington boiler some years ago; owing to the expense incurred in preparing the dust fuel he had found the dust fuel only profitable with low-grade coal; but then the flame tended to go out; soft water was, moreover, imperative, lest the intensely hot flame burn the tubes, and the insulation was a weak point in the Bettington boiler; he also expected trouble from the action of the ash on the firebricks, unless the ash and lining were either both acid or both basic. Mr. King partly admitted the force of these objections, but thought that even a fairly good coal would show an increased efficiency when pulverised; coke breeze should be very finely pulverised; there had been no trouble with the flame going out.

Improvements of Chefoo Harbour.—Mr. G. Rickard, engineer-in-chief to the Chefoo Harbour Improvement Commission, has made the following report on the work done from July 1 to December 31, says *The London and China Telegraph*:—*The Breakwater.*—Stone dumping has been continued on the first 1,800 ft. of the foundation, about 11,000 tons having been deposited in the half-year. A length of 900 ft. is practically ready for the placing of the masonry blocks, and 600 ft. has the heavy stone protection on the slopes. The first caisson has been launched and completed, and was successfully sunk in its position on the prepared foundation at the south head of the breakwater in September, since when some 150 cub. yards of concrete and 100 cub. yards of sand filling have been deposited in it. Block-setting was commenced at the beginning of November, and 29 of the lower blocks have been placed in position. The making of masonry blocks on the West Beach was continued till stopped by frost about the middle of December, 569 large ones and 1,095 small ones, containing altogether nearly 11,000 cub. yards of masonry, being completed in the six months. The total quantity of blocks made to date is—large ones 30 per cent. and small ones 95 per cent. of the total required. *The Mole.*—Good progress has been made during the last six months with the under-water work. Some 250,000 cub. yards of good, hard sand have been dredged from the north-west part of the bay and deposited in the mound. Over 62,000 superficial yards of bushwood zinkstuks have been constructed on shore, and sunk in position on the mole to form the foundation and protect the slopes of the mound; 1,000 piles have been driven, and 9,000 tons of rubble dumped on the zinkstuks. The construction of the caisson for one end of the quay wall has been commenced on the slipway at the Bluff, and 30 cub. yards of reinforced concrete have been deposited (in forming the caisson); 133 blocks for the quay wall, containing 1,900 cub. yards of masonry, have been made at the west beach. *Plant, materials, &c.*—The jetty for loading large masonry blocks has been constructed, and the trolley lines leading from the block yard to the same have been laid and put into use. Some 1,300 tons of cement have been received on the works, also over 60 tons of reinforcing steel.